A PROPOSED METHOD FOR

THE FUNCTIONAL ANALYSIS OF MAN-MACHINE ACTIVITY

TO AID IN THE DEVELOPMENT OF AUTOMATIC DEVICES

A Thesis

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ABSTRACT

During recent years, there has been considerable effort made by various groups to advance the development of automatism in industry. An excellent example of this work is the "automation" program inaugurated at the Ford Motor Company.

Since the development of automatic machines will necessarily result in the transfer of functions and skills from the man to the machine, it would seem desirable to have available some method for determining the detailed functions performed by the man. This, then, is the objective of this thesis:

To develop a method for the analysis of human activity to determine the functions performed.

The steps followed in the development of the method were:

(1) Development of a system of classification of human activity.

(2) Development of a technique for observing and recording the basic data connected with human activity.

(3) Development of a technique for analyzing the basic data.

(4) Development of a method for portraying and summarizing the results.

(5) Application of the method in a test case.

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In developing the system of classification, human activity was first divided into sensory and manipulative activity. Sensory activity was further divided into visual, auditory and tactile activity. A study of the physiology of each sensory system was then made and a list of basic functions for that sensory system was prepared. Finally, these basic functions were used to develop the specific classifications of sensory activity.

The therbligs developed by the Gilbreths were used for the analysis of the manipulative activity.

The particular job chosen for the application of the method was the manufacture, by a skilled operator, of a gear blank on a Gisholt #4 Ram Type Turret Lathe.

The basic observable data of human activity consists of stimulus and corresponding response. In the application of the proposed method response activity was recorded directly, using motion-picture cameras. The stimuli data was then reconstructed from the film record with the aid of additional detailed information concerning the machine and the particular operation performed.

Standard micromotion analysis techniques were used for the analysis of the basic data with some modifications.

For the graphic portrayal of the results of the analysis, a "Total Activity Chart" was developed which is essentially a classified listing of the segments of activity in conjunction with a time scale.

Summaries of the results of the analysis were compiled including:

(1) A compilation of the frequency of occurrence and percent of total time spent in the performance of specific classifications of activity.

(2) A list of functions performed which are related to the control or action of the machine.

The results of the thesis are, first, the proposed method of analysis and, second, an example of its application.

Conclusions drawn from the development of the method and its application in a test case are:

(1) The detailed functions performed by a man in the operation of a machine can be determined by applying the method.

(2) The sensory functions related to the control or action of the machine can be determined.

(3) The frequency of occurrence and the percent of total time spent performing specific functions can be determined.

Recommendations for the further development and improvement of the method are given.

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INTRODUCTION

Development of Automatism

Since the beginning of the Industrial Revolution industrial progress in the purely technical sense has been associated with the transfer of function or skill from the man to the machine. In some instances this process has lead to the complete elimination of some work previously done by man; for example, the invention of spinning machines and looms has almost completely eliminated from modern society the work of spinning and weaving as a manual skill. In other instances this process has lead merely to the partial transfer of function or skill from the man to the machine; an example of this type is the development of the automatic screw machine from the turret lathe.

In more recent times this process of development has lead to the design of complete industrial processes from which the man has been completely eliminated, at least so far as direct participation is concerned. Many of these advances have come in the field of military or naval equipment. Here the driving motives have been time and complexity; either the problems were too complex to be solved by the people available, or they could not be solved in the time allowed. Also, in some cases the man's reaction time was too long to permit

the performance of some function with the desired degree of speed and accuracy. A prime example of this type is the development of the present system of naval gun control[1]. Beginning with a crude system of centralized control and computing at the turn of the century, these systems have developed until now the tracking of targets, computing, aiming, loading and firing of the guns is done entirely without direct human participation.

In industry, since the same urgent driving motives have not been present, this development of fully automatic processes has been more gradual. Since the war, however, certain groups have embarked on programs specifically intended to eliminate as many human functions as possible from certain processes. An excellent example of this work in industry is ECME (electronic circuit manufacturing equipment) developed by John A. Sargrave, a British electrical engineer[2]. This fully automatic equipment can produce three radio circuits a minute which are 80% complete. It should be noted that to make this process possible it was necessary to completely redesign the product. Another excellent example of this type of work is the "automation" program at the Ford Motor Company. Del S. Harder, Ford Vice-President of Production, has been credited with originating this term which has

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[1] "Key to the Automatic Factory, the Computers that Direct Guns Might Also Direct Machines", Fortune, 40 (Nov. 1949), 139-142.

[2] "The First Automatic Radio Factory", Fortune, 38 (Aug. 1948), 90-93.

been defined as "the automatic movement of parts between processing operations and synchronizing such movement with the production rhythm of the machine line"[1]. The first application of these methods to a production line including machine tools was in the production of valve guide bushings at the Ford Highland Park Plant[2]. In this line the castings are ground to length, centerless ground, drilled, reamed, formed, grooved, faced, bored, inspected and phosphate coated, all without being touched by human hands.

The development of these fully automatic processes is not entirely new to industry; some segments of industry employ automatic processes to a high degree. For instance, processes used in the chemical industry are, to a great extent, fully automatic. Also, the mass production bottling and packaging industries have long employed automatic methods of handling and control. The intentional development of automatic methods and processes throughout industry and particularly in the metal working and assembling industries, however, is a new departure.

Factors Which Encourage Automatism

Numerous factors have encouraged this new advance of automatism. In general, these factors may be classified as

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[1] A. H. Allen, Detroit editor of Steel, "Automation", Steel, 126 (April 3, 1950), 102.

[2] Nevin L. Bean, "Automation at the Highland Park Plant, Ford Motor Company", Machinery, 55 (June, 1949), 145.

either economic or technical. J. M. Delfs, Machinery Division, General Electric Corp., has clearly outlined the economic and technical factors which are encouraging this new development[1]. Some of the economic factors are:

(1) Labor rates and costs have increased rapidly in recent years.

(2) Production volume for most products has greatly increased.

(3) Manufactured products have become more complex.

(4) Automatic controls have been found to give better quality and thus lower cost.

(5) Automatic controls have been found to make more effective use of new cutting tool capabilities.

Some of the technical factors are:

(1) New machine control systems have been introduced such as: (a) program control, (b) tracer control, (c) photoelectric line followers, (d) record playback systems, (e) Bullard "Man-au-trol", (f) Warner-Swazey "Electrocycle", (g) Arma Corp. "Arma-matic", etc.

(2) New cutting tool materials have made possible the use of higher speeds and feeds and have thus reduced the machining part of the cycle of production.

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[1] J. M. Delfs, "Automatic Control of Machine Tools", Tool Engineer, 27 (Oct., 1951), 45.

(3) The science of servo-mechanisms has been developed to a high degree of efficiency and this knowledge has become more widely available as an engineering technique.

(4) Various types of computing and memory devices have been developed to a high degree of perfection and the knowledge of their capabilities has become widespread.

(5) The technique of "automation" has been developed making use of hoppers, chutes, magazines, belt conveyors, iron hands, etc. These techniques have been widely publicized.

Proposals for Promoting Automatism

Various approaches to the problem of promoting or developing automation in industry have been proposed. Leaver and Brown, two Canadian physicists, claim that the greatest obstacle to the advancement of automation in industry is the current philosophy of machine design which designs the machine in terms of the product[1]. They propose a new philosophy of machine design in which the machines would be designed in terms of the basic functions they would be required to perform.

A group of Harvard Business School students working under the leadership of John T. Diebold made a study of the

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[1] E. W. Leaver and J. J. Brown, "Machines Without Men", Fortune, 34 (Nov., 1946), 165.

problem of increasing automatism in industry and of the technology available for the solution of the problem[1]. This group concluded that the development of automatic materials handling equipment was the most pressing problem in the development of automatic production processes. The solution proposed by this group is the use of standard production type machines connected by automatic materials handling and inspection equipment.

<u>General Conclusions</u>

In general, it may be concluded that the development of automatism in any segment of industry or the development of an automatic process for the manufacture of a particular product may require the solution of any or all of the following problems:

(1) The redesign or modification of the product to make it more adaptable to automatic manufacture.

(2) The redesign of the basic process of manufacture to make it more adaptable to automatic methods.

(3) The redesign or modification of machine tools to adapt them to automatic loading and unloading and to adapt them for automatic control.

(4) In some cases detector or receptor devices may require development or application.

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[1] John T. Diebold, et al, "Making the Automatic Factory a Reality", a Harvard Business School Report.

(5) Finally the integration and regulation of all the elements of the process by some control unit will be required.

OBJECTIVE

By definition, an automatic machine or process is "self-acting" or "self-regulating"; it is a process which acts or performs without human control. Since the development of automatic machines or processes will result in the transfer of functions and skills from the man to the machine, it would seem natural and logical to ask the question: What functions are performed by the man which are essential to the process and must, therefore, be incorporated into the machine or automatic device? To answer this question it would seem desirable to have available some technique or method of analyzing human activity to determine the functions being performed. This, then, is the objective of this investigation:

> To develop a method for the analysis of human activity to determine the functions performed.

One of the questions asked by the Harvard Group in their study of automatism in industry was: "What is the function of man in our present manufacturing processes?"[1] In answering the question this group listed the following broad functions performed by men in industry today:

(1) The operation of production type machines.

- (a) Loads and unloads the machine.
- (b) Visually inspects each piece as it is removed from the machine.

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[1] *Ibid.*

(c) Watches the machine to detect any irregularities in its performance.

(2) Operation of non-production type machines.

(a) All the functions listed above.

(b) Moves the tool or workpiece to perform the required machining operation.

(c) Typically has much greater control over the movement of the various parts of the machine.

(3) Paper work.

(4) Materials handling.

(5) Production, cost and quality control.

(6) Inspection.

(7) Supervising semi-automatic processes.

(8) Machine set-up work.

(9) Maintenance work.

(10) Assembly.

The consideration of these functions in terms of other questions asked by the group lead to several very useful conclusions, one of which was previously cited; however, this list would be of very little use to the machine or process designer actually faced with the problem of designing an automatic device. For this purpose a much more detailed knowledge of the functions of the existing man-machine combination would be required. It should be understood, then, that the objective to be achieved by this proposed analysis method is a much more detailed determination of the functions performed.

SCOPE OF THE THESIS

The scope of the present study has been limited to the development of the method of analysis. The logical steps in the development of the method are:

(1) Development of a system of classification of human activity.

(2) Development of a technique for observing and recording the basic data connected with human activity.

(3) Development of a technique for analyzing the basic data.

(4) Development of a method for portraying and summarizing the results.

(5) Application of the method in a test case.

In practice, the application of the method did not occur as a separate step, rather, it was necessarily an integral part in the development of the method. This relationship will be maintained in the following discussion.

Choice of Application

Since most of the time spent on this investigation was in the development of the method of analysis, it was necessary to severely limit the number and variety of applications of the method. For this reason, the type of work to be analyzed was first limited to repetitive jobs in the metal cutting industry. Then a typical job on a ram type turret lathe was selected for the application of the method. The particular job chosen was the manufacture, by a skilled

operator, of a gear blank on a Gisholt #4 Ram Type Turret Lathe. It was felt that the performance of this particular job on this type of machine would be fairly representative of repetitive jobs in the metal cutting industry.

PROPOSED SYSTEM OF CLASSIFICATION OF HUMAN ACTIVITY

Necessity for a System of Classification

To repeat, the objective of this investigation is the development of a method for the analysis of human activity to determine the functions performed. Analysis is defined as the separation of anything into constituent parts or elements or as an examination of anything to distinguish its component parts separately or in their relation to the whole. An analysis of human activity, therefore, can be thought of as the separation of human activity into its constituent parts or elements. From this definition it is seen that the first requirement for a method of analysis is a system of classification of human activity into detectable segments or parts. Furthermore, since the ultimate objective of the analysis is to determine the function or purpose performed by the activity, the classification should be made according to the purpose or duty performed.

Grouping into Sensory and Manipulative Activity

The directly observable data concerning human activity is of two forms: stimulus and response. In this respect a stimulus may be thought of as anything which can be detected by an individual which elicits a response. It is the function of the sensory processes to act as the receptors of stimuli. Associated with the stimulus is an act of the body or its members (usually some movement) which is termed the response.

In performing work, the most typical activity is the manipulation of objects or controls by the hands; consequently, in this study, response acts will be referred to as manipulative activity. From these considerations two broad classifications of human activity may be established, namely:

(1) Receptor or sensory activity.

(2) Effector or manipulative activity.

<u>Use of Therbligs</u>

In this method the standard therblig classifications have been used for the analysis of the hand motions and manipulations[1]. Since most of the manipulative activity occurs in conjunction with the therblig <u>Use</u>, this is not entirely satisfactory; however, the descriptions given with the therbligs overcome this difficulty. In this connection, only the motion of the hand with regard to the object with which it is in contact is described; the end function performed by the machine as a result of this activity is described separately.

<u>Further Division of Sensory Activity</u>

Sensory activity can be further divided according to the sensory system which acts as the receptor of the stimulus. For the purposes of this study only those sensory systems which act as the receptors of exterior stimulus are of interest.

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[1]Marvin E. Mundel, <u>Motion and Time Study</u>, (New York: Prentice-Hall, 1950), 226.

The one exception to this is the kinesthetic sense, certain functions of which have been grouped with tactile functions for the purpose of simplifying the analysis. Thus, sensory activity may be further sub-divided according to:

(1) Visual activity.

(2) Auditory activity.

(3) Tactile activity.

General Approach to the Development of Specific Classifications

In developing the specific classifications of activity for each sensory system, the first step has been to describe briefly the physiology of the particular sensory system. From this description a list of the elemental functions or capabilities of the particular sensory system has been prepared.

When examined it is seen that these elemental functions of a particular sensory system are usually concerned with the elemental qualities or characteristics of objects. Typically, however, the individual observes objects not in terms of their elemental qualities but, rather, as "total" objects which result from the subconscious combination of all the elemental qualities of the object. This is an example of the psychological process of perception[1].

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[1] Floyd L. Ruch, Psychology and Life, (third edition; Chicago: Scott, Foresman and Company, 1948), 277.

Also, by the subconscious perception of various "cues" connected with the particular sensory processes, the individual is able to determine the spatial relationships of objects. Finally, the response of an individual to a particular stimulus depends upon the meaning associated with that stimulus. This association of meaning with stimulus is another example of the process of perception[1]. In the development of the sensory functions, these concepts of the perceptive processes have been used to develop typical functions which are combinations of the elemental functions connected with the sensory system; these will be called compound functions. Also, these concepts have been used in the development of specific classifications of sensory activity in which the purpose performed is more closely related to the meaning attached to a particular stimulus than to the fundamental nature of the stimulus itself.

Since the goal of this method of analysis is practical application, the more common or typical of these "fundamental" and "compound" functions have been selected as the "basic" functions or capabilities of the particular sensory system. These "basic" functions of the particular sensory system are used to develop the specific classifications of sensory activity. It is essential, here, that the

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[1]J. R. Kantor, Principles of Psychology, I., (Bloomington, Indiana: The Principia Press, 1949), 249.

distinction between the functions or capabilities of a particular sensory system and the specific classifications of sensory activity be clearly understood. These specific classifications of sensory activity should be thought of as descriptions, in terms of purpose performed, of detectable segments of sensory activity; as such, they consist of two essential parts, namely, a description of the sensory class (i.e., looking, listening or touching) and a description of the purpose or intent of the activity. Each classification is defined along with its beginning and end points and a mnemonic abbreviation is assigned. Where useful, examples are given. A concise summary of the classifications is included in the appendix for quick reference.

CLASSIFICATION OF VISUAL ACTIVITY

As a background for the development of the classifications of visual activity, a brief description of the physiology of the eye and the psychological processes of the sense of sight will be given. Excellent expositions of this material can be found in any standard encyclopedia[1] or textbook of general psychology[2,3].

In outline, the physiology of the visual sensory system might be described as follows: light impinges upon the cornea of the eye, is transmitted through the pupil to the lens by which it is focused upon the retina of the eye. The retina is a light-sensitive surface and transforms the light energy into nervous impulses which are transmitted by the optic tract to the occipital lobe or visual area of the brain cortex.

The Eye

The important functional components of the human eye are the pupil, iris, lens and retina. The pupil is the opening through which the light passes; its size is varied by the reflex action of the iris in response to varying intensities

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[1] "Vision and Sight", The Encyclopedia Brittanica, (1950), XXXIII, 199.

[2] Floyd L. Ruch, op. cit., 239.

[3] Wayland F. Vaughan, General Psychology, (revised edition; New York: The Odyssey Press, 1939), 83.

of light. The lens focuses the light from the momentary "object of attention" onto the retina; its curvature is varied by reflex action for objects at different distances.

The Retina

The retina is by far the most complex and important element of the eye and will be described in more detail. The surface of the retina consists of a multitude (about 7,000,000) of cones and rods, each connected by nerve tissue to the main optic tract. The arrangement of the cones and rods is non-homogenous. Only cones are found at the center of the retina (called the fovea centralis) and here they are packed very close together. Toward the periphery of the retina the cones become fewer and the rods more numerous, until - on the outermost periphery - there are very few cones. The connections of the cones and rods to the optical fibres of the optical nerve are also non-homogenous. Near the center of the retina, each cone or rod is connected to an individual nerve fibre of the optic tract. Further away from the fovea several rods (or cones) will be joined to a single optic nerve fibre until at the periphery of the retina, as many as 200 may be joined together on a single "party line". Each cone or rod by a chemical process (the exact nature of which is not known) serves as an elementary "detector" of light energy. Light of sufficient intensity impinging on the sensory element causes nerve "pulses" to be transmitted to the brain cortex. Variations in intensity of

the light cause the frequency of the pulses to vary - increased intensity causing increased frequency. The rods and cones respond differently to light energy. Evidence indicates that the cones function in some way (not known exactly) as the detectors of color, whereas, the rods can detect only brightness. Also, the rods are more sensitive than the cones and thus are used under conditions of dim illumination.

<u>Depth Perception</u>

Since the retina is a surface, the single eye is capable of producing only a two dimensional picture; typically, however, we perceive our surroundings in three dimensions. This visual perception of depth or distance is made possible by various phenomenon connected with the sense of light. The principal factors which make possible the visual perception of depth are:

(1) Binocular retinal disparity. Because of the separation of the eyes, the images produced on the retinas by relatively near objects are different. This disparity is one factor in the visual perception of depth.

(2) Convergence. Again, because of binocular separation, the eyes must be directed to converge on the stimulus object and this provides another cue for the perception of depth.

(3) Accomodation. The accomodation of the eyes for objects at different distances affords another cue for

the perception of depth.

Secondary factors in depth perception are:

(1) Distinctness of objects seen at a distance.

(2) Lights and shadows.

(3) Relative position of the objects.

(4) Relative rates of apparent motion.

(5) Relative size of known objects.

Directional Characteristics of the Eye

The preceding discussion has been concerned primarily with the receptor properties of the eye; i.e., those properties by which the eye functions as a receiver of visual stimuli. In order to receive visual stimuli, however, the eye must be directed toward the particular stimuli object and must be accomodated for the reception of stimuli from that object.

As previously discussed, the center of the retina, the fovea, consists entirely of cones which are closely packed together and each of which is connected by an individual nerve fibre to the occipital lobe of the brain. Also, the cones function under bright (daytime) illumination and are believed to be the detectors of color. Thus it is seen than under daytime conditions of illumination the fovea is the most sensitive area of the retina and, consequently, for most efficient vision the image of the stimulus object must be centered and focused on the fovea. This centering action is accomplished by movements of the eyeball and head

(the eyeball being essentially spherical in shape and capable of being rotated around vertical and lateral axis).

A convenient term for describing movements of the eye is the Line of Sight (LOS) which will be defined in this study as the line from the center of the pupil to the point of fixation of the eye when the eye is vixed on a particular point.

Finally, the eyelid may be activated to cover the eye. This occurs either during sleep or as a reflex action to protect the eye from damage or to lubricate the cornea of the eye.

In conclusion, it is seen that the functions of the eye are of a dual nature - primarily, as a receptor of visual stimuli and, secondarily, as a responder to internal stimuli or nerve action. For a description of the functional activity of the sense of sight to be continuous and complete it should include descriptions of both phases of this activity.

Elemental Functions of Vision

Based upon the preceding discussion of the physiology of the eye and the subconscious perception of various "cues", the following elemental functions or capabilities of the sense of sight may be listed:

(1) The determination of the direction of an object relative to the body.

(2) The detection of the movement of an object within the field of vision.

(3) The determination of the color of light from an object.

(4) The determination of the form or outline of an object.

(5) The determination of the depth or distance of an object.

(6) The determination of the surface finish of an object.

(7) The determination of the intensity of light from an object.

Compound Functions of Vision

These elemental functions or capabilities of vision are concerned with the elemental qualities or characteristics of objects. Typically, however, we perceive combinations of these elemental qualities as other qualities or characteristics or as total objects; i.e., we ordinarily perceive "wholes" and not parts. Thus, by combining certain of these elemental functions of the sense of sight other functions or capabilities are obtained which are quite typical and common to the sense of sight. The more common of these "compound" functions of the sense of sight are:

(1) The determination of the shape of an object - a combination of the perception of outline and depth.

(2) The determination of the size of an object - a combination of shape (outline and depth) and distance.

(3) The determination of the location of an object - a combination of direction and distance.

(4) The determination of the relative position of two objects - a combination of direction and depth.

Selected Basic Functions of Vision

Since the goal of this method is practical application, the more common or typical of these "elemental" and "compound" functions will be selected as the "basic" functions of vision. Those selected are:

(1) The determination of Direction.
(2) The detection of Movement.
(3) The determination of Color.
(4) The determination of Distance.
(5) The determination of Surface Finish.
(6) The determination of Shape.
(7) The determination of Size.
(8) The determination of Location.
(9) The determination of Position.
(10) The determination of Intensity.

The relation between the basic functions of the sense of sight and the basic stimuli which the system is capable of detecting should be understood. A stimulus was described previously as anything in the immediate environment of an individual which can be detected or determined and which elicits a response. Within this meaning, then, the sense of sight may be considered capable of detecting those basic

stimuli underlined in the list above.

These "basic" functions of vision have been used as a foundation for the development of the specific classifications of visual activity which follow. The classes of visual activity have been divided into two groups, response activities and sensory activities, corresponding to the dual nature of the functions of the sense of sight.

The Classifications of Visual Activity

Response Activity

(1) Movement of the Line of Sight (M).

Consists of changing the direction of the LOS of the eye from one object to another object whose location is known.

Begins when the LOS begins to shift from the first object.

Ends when the LOS of the eye is fixed on the second object.

(2) Closed or Covered (CL).

Consists of the time during which the eyelids are closed or the eyes are covered by some opaque object and thus the reception of visual stimuli is not possible except in the gross sense - blinding light, radical changes in light intensity, etc. The purpose of this activity is either to protect the eye from injury by foreign objects or intense light or to lubricate the cornea.

Begins when the eyelids begin to close or when some opaque object begins to cover the eyes.

Ends when the eyelids begin to open or when the opaque object begins to uncover the eye.

Examples: (a) Winking of the eye. (b) Covering of the face with a welding shield.

(3) Wander (W).

Consists of the characteristic movement of the LOS when no purpose is being performed by the visual sense (i.e., no visual stimuli are the object of attention); may include the temporary fixation of the LOS on an irrelevent object or may consist of a random motion of the LOS.

Begins with any random motion of the LOS or the fixation of the LOS on any irrelevent object.

Ends when the LOS begins to move to some particular stimulus object.

Sensory Activity

(1) Movement (MV).

Consists of viewing a moving or rotating object to determine its rate or direction of movement or rotation.

Begins when the LOS becomes fixed on a moving or rotating object.

Ends when the LOS moves from the object or when the movement ceases.

Note: This classification does not include the viewing of the short, slow movements connected with the final positioning of one object relative to another.

(2) Color (CR).

Consists of viewing an object to determine its color or viewing several objects to discriminate between their colors.

Begins when the LOS becomes fixed on a particular object or when the LOS begins to oscillate between several selected objects.

Ends when the LOS begins to move to some different object.

(3) Surface Finish (SF).

Consists of viewing an object to judge the quality of its surface finish.

Begins when the LOS becomes fixed on a particular object or when the LOS begins to move across the surface of the object in some patterned or random way.

Ends when the LOS moves from the object.

(4) Shape (SH).

Consists of viewing an object to determine its shape.

Begins when the LOS becomes fixed on the particular object or when the LOS begins to move across the object in some patterned fashion.

Ends when the LOS moves from the object.

(5) Size (SZ).

Consists of viewing an object to determine its size.

Begins when the LOS becomes fixed on the particular object or when the LOS begins to move across the object in some patterned manner.

Ends when the LOS moves from the object.

(6) Location (L).

Consists of viewing an object to determine its direction and/or distance from the body.

Begins when the LOS becomes fixed on the particular object.

Ends when the LOS begins to move from the object.

Examples: (a) Looking at an object toward which the hand is moving or which the hand is grasping. (b) Looking at "reference" points while walking.

(7) Position (P).

Consists of viewing an object to determine its position relative to another object.

Begins when the LOS becomes fixed on the "central" object in the situation or when the LOS begins to alternate rapidly from one object to the other in the situation.

Ends when the LOS begins to move finally away from one or the other objects.

Examples: (a) Looking at a pointer on a scale to determine its position relative to the scale either for information or to control the final positioning of the pointer.

(8) Intensity (IT).

Consists of viewing an object to determine the intensity of the light from the object.

Begins when the LOS becomes fixed on the particular object.

Ends when the LOS moves from the object or when the intensity has been determined.

(9) Search (S).

Consists of the movement of the LOS of the eye to determine the presence and/or location of a particular object whose precise location is not known.

Begins when the LOS begins to move from the first stimulus object.

Ends when the LOS is fixed on the second stimulus object.

(10) Identity (ID).

Consists of viewing an object to determine its identity.

Begins when the LOS becomes fixed on the particular object, or, if the object is large, when the LOS begins to move over the object in some patterned way.

Ends when positive or negative identification is completed and may or may not consist of a movement of the LOS from the object.

(11) Termination (T).

Consists of viewing an object or exterior activity[1] to detect terminal signals or conditions, i.e., signals or conditions which indicate the initiation or termination of that activity or some related activity.

Begins when the LOS becomes fixed on the object or activity which is the source of the signal.

Ends when the signal is received or when the LOS moves from the object or activity.

Examples: (a) Looking at a traffic signal to detect a change in the signal.

[1]Note: As used here an "exterior activity" means some activity with which the hands are not in direct contact.

(12) Monitor (MR).

Consists of viewing an automatic or uncontrolled activity to detect any abnormal, unusual or undesirable conditions of the activity.

Begins when the LOS becomes fixed on the particular activity.

Ends when the LOS moves from the activity or when some abnormal or unusual condition requiring response is detected.

Examples: (a) Watching the cutting action of a turret lathe when the lathe is operating in power feed. (b) Watching the cutting action of an automatic screw machine.

(13) Control (C).

Consists of viewing a controlled, exterior activity[1] to determine its momentary condition or progress.

Begins when the LOS becomes fixed on the particular activity.

Ends when the LOS moves from the particular activity or the activity ceases.

Examples: (a) Watching the cutting action on a turret lathe when the hand is controlling the feed of the tool.

(14) Ready (R).

Consists of viewing letters, words and/or numerals to determine their meaning.

Begins when the LOS becomes fixed on or moves in a patterned manner across the letters, words and/or numerals.

[1]Note: As used here an "exterior activity" means some activity with which the hands are not in direct contact.

Ends when the LOS moves from the letters, words and/or numerals.

(15) Mathemation (MM).

Consists of viewing some mathematical array to determine its end or resultant meaning.

Begins when the LOS becomes fixed on the mathematical display or begins to move in a patterned way across the mathematical display.

Ends when the LOS moves from the display or when the corresponding response is completed.

Examples: (a) The activity of the eye while adding columns of figures. (b) The visual activity connected with the multiplication of numbers.

(16) Count (CT).

Consists of viewing several objects to determine their total number.

Begins when the LOS begins to move from object to object in some patterned way.

Ends when the LOS moves from the objects or when the total has been determined.

CLASSIFICATION OF AUDITORY ACTIVITY

As a basis for the classification of auditory activity a brief description will be given of the physiology of the components of the ear[1,2]. The ear, the sensory organ of hearing, consists of five main parts: the outer ear, the middle ear, the inner ear, the organ of Corti and the auditory tract to the brain. The operation of the auditory sensory system may be described briefly as follows: sound waves are received by the outer ear, transmitted by the middle ear to the inner ear where the sound energy is transformed by the organ of Corti (the auditory detector organ) into nerve impulses which are then transmitted to the auditory centers of the brain.

The Ear

The visible portion of the ear consists of the expanded flap called the auricle and the meatus, the tube which terminates in the eardrum. The auricle serves no auditory purpose since its dimensions are too small in relation to the wave-lengths of sound to effect the direction of the waves.

The middle ear is an irregularly shaped, air filled cavity in the temporal bone in which is suspended, by the

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[1] "Hearing", The Encyclopedia Brittanica, (1950), XI, 297.

[2] Floyd L. Ruch, op. cit., 262.

tympanic muscles, the auditory ossicles which is essentially a mechanical connection between the eardrum and the oval window of the inner ear.

The inner ear is a complex space in the temporal bone and is divided into two primary functional parts; first, the vestibule and semicircular canals which perform functions in connection with bodily equilibrium of the organism and, second, the cochlea which contains the auditory sensory apparatus.

The Cochlea

The cochlea is a spiral shaped space divided into two main parts, the vestibular and tympanic canals which are joined at the end of the spiral. The basilar end of the vestibular canal is separated from the middle ear by the oval window to which is attached the stapes, a link in the auditory ossicles. The basilar end of the tympanic canal is separated from the middle ear by another membrane, the round window. The partition between the vestibular canal and the tympanic canal is made up, in part, by a membrane called the basilar membrane upon which lies a complex structure, the organ of Corti, in which the auditory receptor cells, the hair cells, are imbedded. Another membrane, called Reissner's membrane, separates the organ of Corti from the vestibular canal. This space is filled with another fluid called endolymph. Each hair cell is connected to an individual nerve fibre forming part of the auditory tract to the brain. Vibrations of the foot plate at the end of the stapes cause

pressure variations (and consequent motion) in the fluids in the cochlea which are detected by the hair cells and transformed into nerve pulses which are then transmitted to the brain.

Theories of Hearing

The action of the organ of Corti is not precisely known particularly as concerns the detection of the pitch variations of sound. Several theories have been advanced to explain this phenomenon. One of the earliest and most popular theories, known as the resonance theory, is based upon the idea that the cochlea contains a series of resonators which by their physical characteristics respond only to discrete frequencies of sound. Another theory, the frequency theory, is based on the idea that the pressure waves are converted directly into nerve pulses of corresponding frequency which are then transmitted to the brain. Both of these theories have serious limitations and a later theory - the resonance-volley theory - incorporates principles of both the earlier theories in an effort to overcome these difficulties. The exact nature of the hearing process, however, is not known.

Sound

Physically, sound is a wave propogation of energy in the form of pressure and density variations in the media of transmission. As such, its essential character is determined

in terms of the frequency, intensity and form of the wave motion. These physical properties of sound correspond to the psychological phenomenon of pitch, loudness and timbre. Pitch and loudness are characteristics of the simplest sounds (pure tones). Timbre, on the other hand, is a function of the complex combination of these two fundamental qualities, since it depends upon the number and intensity of the various overtones in the sound. The exact nature of auditory detection is not known; however, it may be assumed from the above discussion that the simplest and most elemental function performed by the ear or the sense of hearing is the determination of pitch and loudness.

Binaural Phenomenon

The determination of the direction of sounds by hearing alone is generally inaccurate. In addition to the inherent limitations of the sense of hearing for this purpose, the very nature of the propagation of sound limits the accuracy of determination; i.e., sound waves will bend around corners and reflect off of surfaces so that the true direction of the source cannot be determined from the terminal direction of the sound at the ear. The determination of the direction of a sound is made possible by the subconscious perception of four types of binaural differences, namely, the relative intensity, time of incidence, phase and complexity. The action of these various cues is dependent upon the

[illegible]

[illegible]

[illegible] to form [illegible]

[illegible]

frequency and timbre of the sounds. These factors will not be discussed here except to note that high tones are localized with difficulty, low tones more readily and noise with comparative ease. Positions up and down or ahead and behind are not distinguished by binaural cues.

From this discussion of the physiology of the ear and the subconscious perception of various "cues" connected with the auditory system, the following basic functions or capabilities of audition may be listed:

(1) The determination of the Pitch of a periodic sound (tone).

(2) The determination of the Loudness (or intensity) of a sound.

(3) The determination of the Timbre of a sound (including the detection of noise).

(4) The determination of the Direction of a sound.

(5) The detection of the Movement of the source of a sound.

(6) The gross determination of the Distance to a source of sound.

The Classifications of Auditory Activity

(1) Loudness (LD)

Consists of listening to a sound to determine its loudness.

Begins with the reception and/or attention to the sound.

Ends when the reception or attention to the sound ceases or its loudness has been determined.

(2) Pitch (PC)

Consists of listening to a single tone or several tones simultaneously to determine their pitch.

Begins with the reception and/or attention to one or more tones.

Ends when the reception or attention ceases or when the pitch has been determined.

(3) Timbre (TB)

Consists of listening to one or more tones to determine their timbre either separately or together.

Begins with the reception and/or attention to one or more tones.

Ends when the reception or attention ceases or the timbre has been determined.

(4) Location (L)

Consists of listening to a sound to determine its direction of incidence and/or estimate the distance to its source.

Begins with the reception and/or attention to the sound.

Ends when the reception or attention ceases or when the direction of incidence of the sound and/or the distance to

the source have been determined.

(5) Movement (MV)

Consists of listening to a sound to detect and/or determine the direction of any movement of the source of the sound.

Begins with the reception and/or attention to a sound.

Ends when the reception or attention ceases or the movement has been determined.

(6) Identity (ID)

Consists of listening to a sound to determine the identity of the sound and/or its source.

Begins with the reception and/or attention to the sound.

Ends when the reception or attention ceases or when the sound has been identified.

(7) Search (S)

Consists of listening to or for a particular sound to detect its presence and determine the location of its source.

Begins with the attention to or for the particular sound.

Ends when the attention ceases or the presence of the sound is detected and the location of the source is determined.

(8) Termination (T)

Consists of listening to or for a particular sound to detect the initiation or termination of some activity connected with the particular sound.

Begins with the attention for or to the particular sound.

Ends with the reception or cessation of the sound.

(9) Monitor (MR)

Consists of listening to the sounds from an automatic activity to detect any abnormal, unusual or undesirable conditions of the activity.

Begins with the reception and/or attention to sounds from the activity.

Ends when the reception or attention ceases or when some abnormal or unusual condition is detected.

(10) Control (C)

Consists of listening to the sound from a controlled activity to determine its momentary condition and/or progress.

Begins with the reception and/or attention to the sound from the activity.

Ends when the reception or attention ceases.

(11) Speech (SP)

Consists of listening to speech to determine the meaning implied.

Begins with the reception and/or attention to speech.

Ends when the reception or attention ceases.

CLASSIFICATION OF TACTILE ACTIVITY

Sensory Systems of the Skin

In developing the classifications of tactile activity, the sensory system of the skin will first be discussed[1,2,3]. The surface of the skin contains several kinds of sensory nerve endings which act as the receptors for a variety of stimuli. The structure of these end-organs varies considerably and the exact nature of the process by which they transform stimuli into nerve pulses is not known. The three fundamental types of touch sensation are pressure, temperature (hot and cold) and pain. The pain sensations are not of interest in this study and will not be discussed.

Distribution of Sensitivity

The distribution of the sensory end-organs over the surface of the skin is not uniform. When the surface of the skin is explored with very fine stimuli, it is found that sensitivity to stimulation is limited to certain very small areas. These "spots" are distinct for each kind of stimulus so that there are separate spots for pressure, heat, cold and pain. The sensitivity of a given region of the

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[1]"Skin, Sensory Functions of", The Encyclopedia Britannica, (1950), XX, 750.

[2]Tufts College Institute for Applied Experimental Psychology, Handbook of Human Engineering Data, (second edition), Part V.

[3]Floyd L. Ruch, op. cit., 268.

skin depends upon the density of distribution of these spots. Generally the distribution of these stimulus spots varies together for all four senses; however, there are exceptions - for one, the finger tips, which are highly sensitive to pressure but relatively insensitive to pain. This distribution of the sensory system makes possible the detection of the location of a particular touch stimulus on the skin surface and the rough determination of the area of contact of the object with the skin. Since this function or capability of localization and determination of area is so closely associated with the stimulus itself, this function will not be distinguished separately in the following discussion.

Pressure Sense

The sensation of pressure is experienced when an object contacts the skin and produces a displacement or movement of the sensory end-organs. When the object is vibrating the sensation of vibration is experienced. Thus, the pressure sensory system is capable of detecting static or moving contact and vibrations of an object in contact with the skin. In this study, for convenience, static contact will be termed simply "contact" and moving contact will be termed "slip". The pressure sense is subject to fatigue and adaption effects and, consequently, the pressure sensation of a static contact will cease after a certain time.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] 30

[illegible]

Thermal Sense

The sensation of temperature is of two kinds; first, the sensation of warmth and, second, the sensation of cold. Corresponding to these two kinds of sensation the skin has two separate receptor systems - cold spots and warm spots. The stimulus for these receptor organs is the transfer of heat to or from the surface of the skin. The stimulus for the warm spots is the transfer of heat to the skin while that for the cold spots is the transfer of heat from the skin. Objects which are at the same temperature as the skin do not stimulate the sensation of temperature. Adaption of the thermal sensory system occurs after continuous exposure to some temperature stimulus; i.e., the "thermal zero point" or "point of indifference" varies with continued exposure. Thus, the thermal sensory system is capable of detecting the transfer of heat to or from the skin or the difference in temperature between the skin and objects in contact with the skin. This capability or function will be referred to here as the detection of temperature.

Basic Tactile Functions

From the preceding discussion of the tactile sensory systems, the following basic functions may be listed:

(1) The detection of the contact of an object with the skin.

(2) The detection of slip of an object in contact with the skin.

(3) The detection of vibration of an object in contact with the skin.

(4) The detection of the temperature of an object relative to the temperature of the skin.

Kinesthesis[1,2]

The discussion of the sensory systems to this point has been concerned with the exterioceptors, i.e., the sensory organs which act as the receptors of external stimuli. There is another group of sensory systems called proprioceptors which consist of receptors which react to internal stimuli. Proprioception, in turn, is subdivided into two parts - kinesthesis, which is concerned with the movements and position of the body members and equilibrium which is concerned with the orientation of the body in space. Of the two, only kinesthesis is of interest here.

The receptors of the kinesthetic sense are nerve cells located in the muscles, tendons and joints of the body. When the body members move these receptors are stimulated by stretch and pressure and produce the kinesthetic sensations of movement and position of the body members and, also, the force applied by the body members. When associated with some

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[1] Handbook of Human Engineering Data, op. cit.

[2] Floyd L. Ruch, op. cit., 272.

particular external object or activity, these kinesthetic sensations provide information concerning external objects or conditions. Thus, through the perception of kinesthetic sensations the following functions may be performed:

(1) The determination of the <u>location</u> of objects in contact with the body extremities.

(2) The detection of the <u>movement</u> of objects in static contact with the body extremities.

(3) The determination of the <u>force</u> of reaction of an object in contact with some body extremity to the force applied.

(4) The determination of the <u>weight</u> of an object held by the hand.

In order to simplify the analysis technique and the portrayal of the final results, these kinesthetic functions have been grouped with the touch functions in the development of specific classifications of "tactile" activity.

<u>The Classifications of Tactile Activity</u>

(1) <u>Vibration (V)</u>

Consists of touching an object to detect the presence and/or determine the character of the vibrations of the object.

Begins with contact and/or attention to the character of the vibrations.

Ends when contact or attention ceases or when the character of the vibration has been determined.

(2) <u>Temperature (TR)</u>

Consists of touching an object with the hand or fingers to determine its temperature relative to the hand.

Begins with contact and/or attention to the temperature of the object.

Ends when contact ceases or when the temperature has been determined.

Note: This may include placing the hand in close proximity to an object for this purpose.

(3) <u>Location (L)</u>

Consists of touching an object to determine its direction and/or distance from the body.

Begins with contact with the object.

Ends when contact ceases or the location has been determined.

(4) <u>Weight (WT)</u>

Consists of holding an object in suspension with the hand to determine its weight.

Begins when the body becomes suspended.

Ends when the suspension ceases or the weight has been determined.

(5) <u>Grasp Control (GC)</u>

Consists of determining the touch stimuli (such as slip, contact, force) from an object which the hand is grasping, holding or using to gain and/or maintain effective control over the object.

Begins when the hand begins to grasp a particular object.

Ends when the hand ceases to touch the object.

Note: This activity may occur simultaneously with other tactile activity.

(6) <u>Surface Finish (SF)</u>

Consists of touching a surface by random or patterned motions of the hand or fingers to determine the quality (roughness or smoothness) of the surface finish.

Begins when the hand touches the surface.

Ends when contact or motion of the hand or fingers ceases or the quality has been determined.

(7) <u>Position (P)</u>

Consists of touching an object to determine its position relative to another object. May consist of touching the two objects simultaneously with one or both hands or detecting the force of reaction against the hand when the two objects are in contact.

Begins when the hand or hands touch the objects.

Ends when contact ceases or when the final position of the objects has been established.

(8) <u>Shape (SH)</u>

Consists of touching an object to determine its shape.

Begins when the hand touches the object.

Ends when contact ceases or when the shape of the object has been determined.

(9) <u>Size (SZ)</u>

Consists of touching an object to determine its size.

Begins when the hand or hands touch the object.

Ends when contact ceases or the size of the object has been determined.

(10) <u>Search (S)</u>

Consists of a random (groping) or patterned movement of the hand or hands through an area or over a surface to detect the presence and/or locate a particular object (may be a vibrating source) whose precise location is not known.

Begins when the hand or hands begin to move as described above.

Ends when the hand or hands cease their characteristic motion or when the particular object is located.

(11) <u>Identity (ID)</u>

Consists of touching an object to determine its identity.

Begins when the hand touches the object.

Ends when contact ceases or when identity is established.

(12) Count (CT)

Consists of touching several objects simultaneously or in succession to determine their total number.

Begins when the hand begins to touch the objects.

Ends when contact ceases or when the total number has been determined.

(13) Termination (T)

Consists of touching an object to detect a touch stimulus indicating the initiation or termination of some activity related to the particular stimulus.

Begins with contact and/or attention to or for the particular touch stimulus.

Ends when contact or attention ceases or when the particular stimulus is received.

(14) Monitor (MR)

Consists of touching an object mechanically connected with an automatic activity to detect any abnormal, unusual or undesirable conditions of the activity.

Begins with the reception and/or attention to the touch stimuli from the activity.

Ends when the reception or attention ceases or when some abnormal condition occurs.

(15) Control (C)

Consists of touching some object mechanically connected with a controlled activity to determine its momentary condition and/or progress.

Begins with the reception and/or attention to the touch stimuli from the activity.

Ends when the reception or attention ceases.

(16) Idle (I)

Consists of the period during which the sense of touch is performing no purpose.

Begins when the hand ceases to be in contact with any object.

Ends with contact with any object.

PROCEDURE FOR
COLLECTING AND RECORDING THE BASIC DATA

As previously noted in the development of the system of classification, the observable data of human activity consists of stimulus and corresponding response. This concept led to the division of human activity into sensory activity and response activity. The response activity of the man includes movements of the head and eyes, movements of the body, and movements of the hands (both between controls and in the manipulation of controls). Also, various actions of the machine occur in conjunction with the manipulative activity of the man. Sensory activity was further divided into visual, auditory, and tactile activity.

The response activity of the man and the action of the machine can be recorded for analysis using motion-picture cameras and micro-motion analysis techniques. The description of the sensory activity must necessarily be in terms of the stimuli received. The direct observation and recording of all the stimuli received by a man in the operation of a machine, even for a short period of time, would be an extremely complex problem, particularly for the visual and tactile stimuli. Consequently, the method used for recording the data in this study was to record the response and machine activity on motion-picture film, and to reconstruct the sensory activity and stimuli data from detailed information concerning the machine and the part being manufactured.

Machine Data

For the purpose of reconstructing the sensory activity, the following types of information concerning the machine and the part being manufactured are required:

(1) A background knowledge of the characteristics and operation of the machine.

(2) Detailed information concerning the individual machine controls.

(3) Detailed information concerning the dials and indicators associated with the machine.

(4) Detailed information concerning the machine sounds which occur during the manufacture of the particular part.

(5) Detailed information concerning the particular part being manufactured.

Specific details of the information required and the methods used for collecting this information follow.

First, a careful study of the operation and maintenance pamphlets for the particular machine should be made in order to gain a background of knowledge concerning its characteristics and operation. If the analyst is not familiar with the machine, some skilled operator should be requested to explain the details of the machine and its operation. If possible, the analyst should operate the controls of the machine and perhaps produce some parts.

When the analyst has become familiar with the machine and its operation, arrangements should be made to collect the

detailed information concerning the machine controls, dials, and machine sounds.

The detailed information required concerning the machine controls includes (for each control):

(1) A complete description of the movements of the control and the corresponding purpose performed.

(2) A complete description of the tactile stimuli produced by the manipulation of the controls, including:

a. A notation of the tactile stimuli produced in terms of the basic tactile stimuli previously listed on page 41.

b. A notation of the source or "object" of the stimuli; i.e., a description of the action of the mechanism producing the tactile stimuli.

c. A complete description of any visual stimuli (other than the actual motion of the control) which may be produced by the movements of the control. This description should be made in terms of the basic stimuli previously listed on page 23.

The detailed information required concerning the dials and indicators associated with the machine includes (for each):

(1) A detailed description of the nature of the movement of the dial or pointer and the controls (if any) with which the dial is associated. Also, notation should be made of the graduations of the dial or scale and the location of any fixed reference indices.

(2) A detailed description of the visual stimuli produced by the dial in terms of the basic visual stimuli previously listed on page 23.

In this particular application, the information concerning the machine controls and dials was collected and recorded together. The assistance of the machine operator was obtained and the analyst actually operated the various controls to determine the required information. No data sheet for the recording of this information was used. The information was prepared and presented in typewritten form, as can be seen by referring to Appendix B.

Job or machine sounds usually occur in conjunction with the use of some machine control. They may also occur in conjunction with some typical machine action (such as cutting action) or in conjunction with some automatic operation. For the collection and recording of this information, a form was developed with columns for the following information:

(1) Associated Control Activity. A specific description of the movement of the control associated with the particular sound.

(2) Source. A description of the action of the machine mechanism which produces the sound.

(3) Time Key. Some key (such as control position) for determining the time of occurrence of the sound from the film record.

(4) Characteristics. A description of the sound in terms of its fundamental qualities such as: Loudness, duration, pitch (if any) and timbre.

(5) Significance. The significance (in terms of machine action or condition) of the occurrence of the particular sound.

This information was obtained in much the same way as the information concerning the controls and dials, viz., with the assistance of a skilled operator and by the actual manipulation of the controls of the machine.

Finally, information concerning the part being manufactured in the particular job chosen for study should be obtained. The following information is required:

(1) A sketch of the part.

(2) Notation of the feeds and speeds used.

(3) A detailed description, in sequence, of the operations required to make the part.

This information should usually be available in the form of a process sheet for the manufacture of the particular part; this was the source of the information used in this study. A copy of the process sheet for the job is included as Appendix A.

Film and Sound Recording Technique

The second major step in the application of the method and recording the basic data is making the film and sound record of the performance of the particular job. As stated

previously, motion-pictures were taken of the performance of the particular job. This provided a detailed record of the performance of the job. Standard micro-motion study filming techniques were used[1]. Some modifications of technique were made to provide for the simultaneous filming of separate activity and the recording of sound. Sound recordings may or may not be required for this type of analysis depending upon the detail and accuracy desired. When accurate data concerning the time of occurrence of sounds is needed and no "keying" action of the machine is available, the sound recordings may be required. Sound recordings were taken of this particular job and the recording method for this procedure will be described. This record was not used in the analysis, however, since adequate "machine action keys" were available to determine the time of occurrence of the significant sounds from the film record.

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[1] M. E. Mundel, op. cit., 208.

Film Record

A film speed of 16 frames per second (or 1000 frames per minute) was used. Two cameras were used as follows:

(1) "Face" Camera. The purpose of this camera was to record accurately the movements of the operator's head and eyes. The analysis of this film record provides an accurate determination of the time of movements of the Line of Sight. Factors which were considered in setting up this camera:

(a) The camera was located to parallel the normal line of sight of the operator as nearly as possible. This required getting as low as possible, since the operator typically looks down to operate the machine.

(b) The camera was located as close to the operator as possible to simplify determinations of changes in the LOS.

(c) The camera was panned to insure that the operator's head was in the field of the camera at all times.

(d) A light was located to illuminate the operator's eyes.

(2) "Side" Camera. The purpose of this camera was to record the movements of the operator's hands and head. Also, any controls or tools that the operator actually manipulates were included in the field of this camera.

Factors considered in locating this camera:

(a) The camera was located to one side of the operator and at a distance of about fifteen feet. Camera height was approximately six feet.

(b) Lights were located to illuminate the side of the head, the hands and the machine controls.

Sound Record

The "job sounds" which are of most interest are: (1) tool noises and (2) machine control noises. The microphone was placed close to the operator and directed to facilitate the "pick-up" of the desired sounds. When possible, the recording should be made when other machines in the vicinity are not in operation in order to reduce the "background noise level". A directional microphone might also be used and should be directed to minimize pick-up of "motor noise". A standard Revere magnetic tape recorder was used.

Time Record

Since the record of activity is made in three parts, an accurate measurement of time in each record is essential in order to synchronize the analysis elements. The use of some synchronizing signal is required.

(1) Film. Time record on the film may be made by using a microchronometer in the field of the camera or by using synchronous motor driven cameras. Note: the inclusion of a microchronometer in the field of view of the "face camera" would be undesirable. In this application, synchronous motor cameras were used.

(2) Synchronizing signal. Some signal to provide a common time reference in all three records is required. This was

provided by using "clap boards".

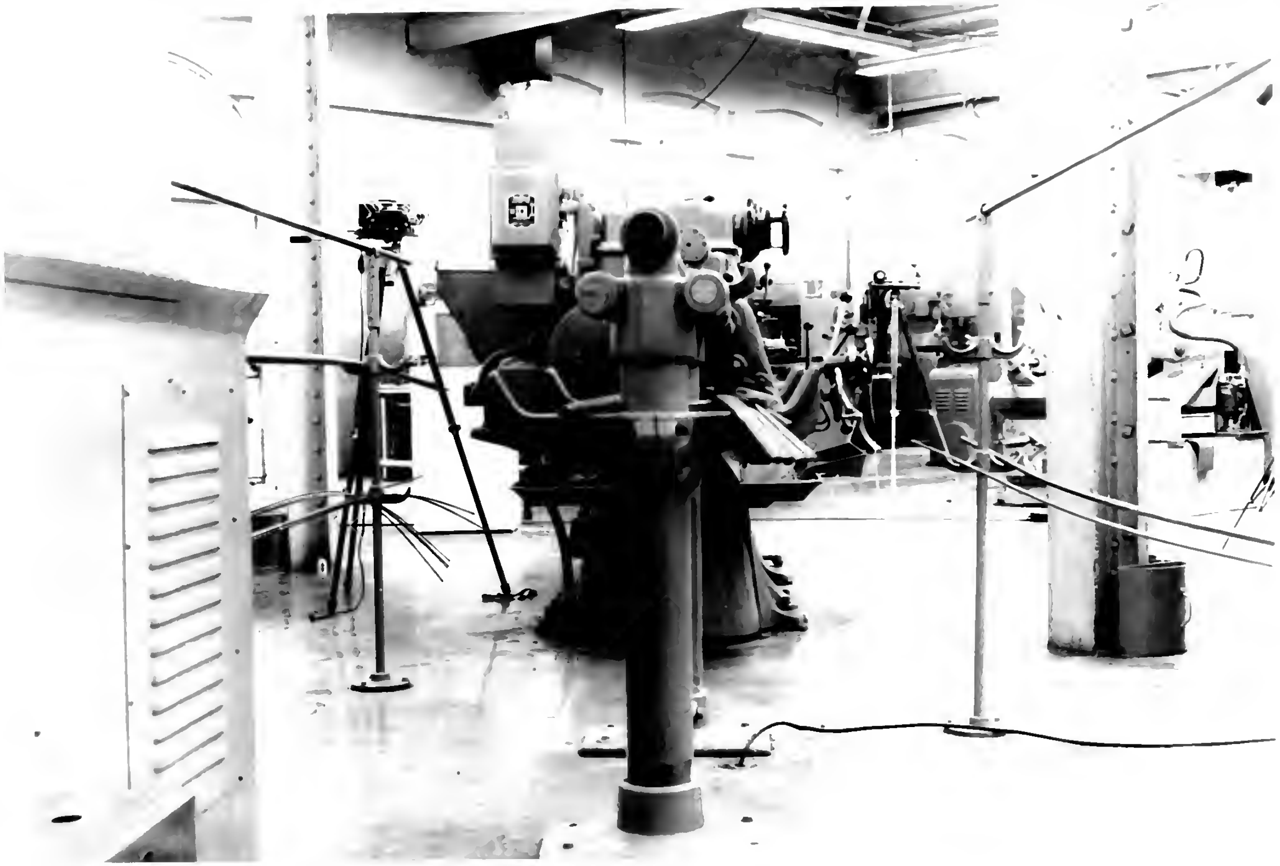
Personnel Required

In addition to the machine operator, the following assistance was found desirable:

(1) "Face" camera operator.

(2) "Side" camera operator.

(3) Sound recorder operator and "director".



LOCATION OF CAMERAS

PROPOSED TECHNIQUE FOR ANALYSIS OF THE BASIC DATA

A frame by frame analysis of the film record was made using standard micromotion analysis equipment, including a single frame projector[1]. Because of the additional machine data which had to be considered and because of the difficulty of correlating the various sensory and manipulative activities, it was found convenient to divide the analysis into the following parts:

(1) Analysis of manipulative, machine and tactile activity.

(2) Analysis of visual activity.

(3) Analysis of auditory activity.

Analysis of Manipulative, Machine and Tactile Activity

Because of the close relationship of the manipulative, machine and tactile activity, they were analyzed together. Being predominately an analysis of response activity this part of the analysis was the simplest to make and was, therefore, done first. Also, making this analysis provided a detailed knowledge of the performance of the job and thus simplified the succeeding analysis of sensory activity. The basic data used for this part of the analysis consisted of:

(1) Side camera film.

(2) Description of machine controls and dials.

(3) Process sheet.

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[1]M. E. Mundel, op. cit., 222.

(4) List of classifications of tactile activity and a table of therbligs.

A form[1] was designed to aid in the analysis of the basic data. Sections of the form were provided for time data, manipulative activity data, machine activity data and tactile activity data. Columns were provided for the following information:

Time Data:

(1) Frame - the frame counter reading at the beginning of the element.

(2) Subtracted time - the inclusive time for that element.

(3) Cumulative time - the total elapsed time to the end of that element.

(4) Corrected time - the corrected time for that element[2].

Manipulative Activity Data:

(1) Symbol - the therblig classification for that element.

(2) Object - the object with which the hand was in contact during that element (if any).

(3) Description - a "pictorial" description of the motion of the hand relative to the object with which it was in contact (if any).

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[1]Appendix "D".

[2]There was a slight variation in the camera drive speeds. To compensate for this all times were related or "corrected" to "face camera time". See Appendix "F" for details.

Machine Activity Data:

(1) Description - a description of the machine action resulting from the concurrent manipulative activity. This might also be thought of as the end result or purpose of the hand motion.

Tactile Activity Data:

(1) Symbol - the mnemonic abbreviation for the selected classification of tactile activity.

(2) Object - the source of the touch stimulus (either the object with which the hand was in contact itself or some machine action).

(3) Stimulus - the stimulus being received or expected during the segment of activity described in terms of the basic tactile stimuli previously listed[1].

(4) Purpose - the immediate, elemental purpose of the sensory activity.

Since the analysis of the manipulative and machine activity is almost identical to standard micromotion analysis, this part was analyzed first for each segment.

In the analysis of the tactile activity, it is extremely important that the objective be kept constantly in mind; i.e., to determine the immediate, elemental purpose being performed by the sensory activity. The sequence followed in this determination was:

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[1]Page 41.

(1) Determine the source of the stimulus.

(2) Determine the nature of the stimulus.

(3) Determine the purpose performed by the sensory activity.

(4) Finally, assign the proper classification of tactile activity.

Analysis of Visual Activity

After the analysis of manipulative, machine and tactile activity was completed, the next step was the analysis of visual activity. The basic data used for this part of the analysis was:

(1) Side camera film.

(2) Face camera film.

(3) Description of the machine controls and dials.

(4) Process sheet.

(5) The classifications of visual activity.

As stated previously, the primary purpose of the face camera film is to provide accurate time data for the movements of the LOS of the eyes. In performing the analysis it was found convenient to project the face camera film and the side camera film concurrently - the face camera film for accurate determination of time and the side camera film for determination of the object of attention of the eye and for determination of the related activity.

A special form[1] was prepared for the analysis of the

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[1] Appendix "C".

basic data. This form is practically identical to the tactile activity section of the Manipulative and Tactile Activity Data Sheet. Columns were provided for the following information:

Time Data (face and side camera):

(1) Frame - the projector frame counter reading at the beginning of the element.

(2) Time - the subtracted time for that element.

(3) Cumulative time - the cumulative time through that element.

Since the face camera times were used as the basic reference, the cumulative times were obtained from that data.

Visual Activity Data:

(1) Symbol - the mnemonic abbreviation of the selected classification of visual activity.

(2) Object - the source of the stimulus.

(3) Stimulus - the basic nature of the stimulus described in terms of the basic visual stimuli[1].

(4) Purpose - the immediate, elemental purpose of the visual activity.

The sequence of steps followed in determining the proper classification of visual activity was the same as for tactile activity:

(1) Determine the source of the stimulus.

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[1]Page 41.

(2) Determine the nature of the stimulus.

(3) Determine the purpose being performed by the visual activity.

(4) Assign the proper classification to the particular segment of activity.

Analysis of Auditory Activity

In this particular application, since adequate "time keys" were available for determining the time of occurrence of the significant sounds, no analysis of the sound recording was required. Instead, the data from the Job Sound Data Sheet was copied directly on the "Total Activity Chart" to be described in the next section.

In the event that an analysis of the sound recording is required to determine the time of occurrence of the various sounds, the use of a simple audio rectifier-filter in conjunction with a pen recording oscillograph would probably be satisfactory. This method was tested.

PROPOSED METHOD FOR PORTRAYING AND SUMMARIZING THE RESULTS OF THE ANALYSIS

With such a mass of detailed information resulting from the analysis of the basic data, some method of portraying and summarizing this information was essential. For portraying the results of the analysis a special form called a "Total Activity Chart" was developed[1]. The general features of this form are similar to the conventional "simo-chart" developed by the Gilbreths for use in micromotion analysis[2].

Total Activity Chart

In the development of this form, the following factors were considered:

(1) The form should provide for a listing of the functions performed according to the major classifications of activity.

(2) The form should provide for notation of the specific classification of each segment of activity.

(3) The form should provide for notation of the important facts concerning each segment of activity.

(4) The form should provide for the correlation of concurrent segments of activity.

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[1]Appendix "G".

[2]M. E. Mundel, op. cit., 226.

(5) The form should provide for the notation of the meaning associated with significant stimuli.

For these purposes, a classified listing of the segments of activity in conjunction with a time chart was found to be satisfactory.

In the manipulative, machine and sensory sections of the chart, the column labels and information are identical to those of the several analysis and data sheets. The "purpose" for the sensory activity has been omitted since this is indicated by the specific classification of the sensory activity.

An additional column labeled "meaning" has been included. The purpose of this column is to provide some means of indicating the major segments of "total" activity, i.e., some means of indicating the major segments of integrated sensory-manipulative-machine activity. Another purpose is to provide a means for indicating the meaning associated with the "significant" stimuli - "significant" stimuli being those which indicate the initiation or termination of some major segment of "total" activity.

Summary of the Results of the Analysis

In addition to the "Total Activity Chart", the following summaries of information have been compiled from the basic data for each major classification of sensory activity:

(1) A compilation of the frequency of occurrence of the specific classifications of activity.

(2) A determination of the percentage of time spent performing each specific type of activity.

(3) A list of the "significant" functions or duties performed by each sensory system - by "significant" functions is meant functions related to the control or action of the machine (as opposed to motor coordination).

Compilation of Frequency of Occurrence And Percent of Total Time

Visual Activity:

	Classification	Frequency	Percent Time
(CL)	Closed	2	0.26
(W)	Wander	1	0.26
(M)	Movement of the LOS	41	6.95
(L)	Location	22	10.4
(MV)	Movement	14	25.0
(P)	Position	35	29.8
(C)	Control	4	8.9
(R)	Read	6	*
(MR)	Monitor	7	18.4

Tactile Activity:

	Classification	L. H. Freq.	L. H. %	R. H. Freq.	R. H. %	Combined Freq.	Combined %
(I)	Idle	31	43.7	35	39.2	66	41.4
(GC)	Grasp Control	39	30.2	63	36.7	102	33.4
(T)	Termination	7	7.3	10	6.4	17	6.8
(C)	Control	6	10.9	7	11.4	13	11.2
(L)	Location	4	4.8	6	2.2	10	3.5
(P)	Position	4	1.5	11	4.2	15	2.8
(MR)	Monitor	1	1.7	0	0	1	0.8

*Occurs in conjunction with other activity. Time not measured but assumed small.

Auditory Activity:

Classification	Frequency	Percent Time
(T) Terminal	14	- *

List of "Significant" Functions

Visual:

(1) Aid in controlling the cutting action by determining its momentary condition and progress.

(2) Regulate advance of tool to work.

(3) Regulate positioning of indexing stop.

(4) Regulate setting of micrometer dial.

(5) Regulate positioning of square turret tools so turret can be indexed.

(6) Determine setting of coarse-fine feed selector.

(7) Control adjustment of coolant flow.

(8) Monitor cutting action to detect unusual conditions.

(9) Observe progress of hexagonal turret retract.

(10) Observe progress of turret indexing.

(11) Observe progress of hexagonal turret advance.

(12) Observe use of carriage binder.

(13) Observe setting of coarse-fine feed selector.

(14) Observe movement of micrometer dial.

(15) Observe positioning of feed engaging lever.

---

*Time not measured but very small.

Tactile:

(1) Detect initiation of cutting action.

(2) Aid in control of cutting action by determining condition and progress.

(3) Control of grasp - gaining and maintaining control of machine controls.

(4) Detect termination of turret indexing.

(5) Control positioning of hand for subsequent grasp.

(6) Control positioning of power feed lever.

(7) Detect contact of carriage with indexing stop.

(8) Aid in controlling the positioning of indexing stop.

(9) Monitor cutting action to detect abnormal conditions.

(10) Control positioning of carriage binder.

(11) Control positioning of coarse-fine feed selector.

Auditory:

(1) Detect initiation of hexagonal turret indexing.

(2) Detect completion of hexagonal turret indexing.

(3) Determine when hexagonal turret can again be indexed (for skip indexing).

(4) Verify proper positioning of power feed lever.

(5) Detect disengagement of power feed lever.

(6) Detect completion of square turret indexing.

(7) Determine when square turret can again be indexed (for skip indexing).

SUMMARY OF RESULTS AND CONCLUSIONS

Results

The results of this thesis are, <u>first</u>, a proposed method for the functional analysis of human activity including:

(1) A system for the functional classification of human activity.

(2) A technique for observing and recording the basic data of human activity.

(3) A technique for the analysis of the basic data.

(4) A method for portraying and summarizing the results.

And, <u>second</u>, an example of the application of the method in a test case.

Conclusions

Based upon the development of the method of analysis and its application in a specific case, the following conclusions are made:

(1) This method of analysis can be applied to determine the detailed functions performed by a man in the routine operation of a machine tool[1].

(2) From this information a list of sensory functions related to the control or action of the machine can be compiled.

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[1]This statement is not meant to imply that the reliability of the method of analysis has been established - reliability meaning the ability of different analysts to produce similar results using the same basic data.

(3) Also, from this information the frequency of occurrence and percent of total time spent in the performance of specific functions can be determined.

<u>Recommendations</u>

For the further development and improvement of this method, the following recommendations are made:

(1) That the reliability of the method of analysis be determined and, where necessary, modifications of the method be made to improve the reliability.

(2) That the validity of the method as an aid in the development of automatic devices be determined. This might be done by comparing the results of an analysis of a man-machine combination performing some work with the actual functions performed by an automatic machine performing the same work.

(3) The actual application of the method to develop an automatic device in some simple work situation.

(4) The development of a color code for use with the "Total Activity Chart".

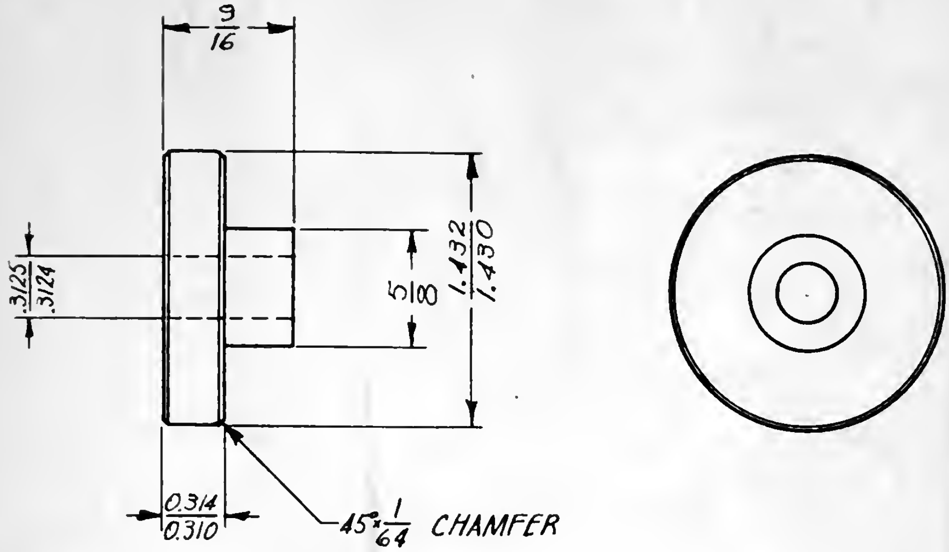
(5) A study of the use of the method for the analysis and measurement of skill.

(6) A study of the application of the method for the determination of training requirements.

APPENDIX A

PROCESS SHEET

FOR THE MANUFACTURE OF A GEAR BLANK



Speeds and feeds pre-set.
RPM - low, 557 rpm.
Feed - .002 in.
Set up for #4 Gisholt.

Hexagonal Turret:

1. Stock Stop - Position stock to length by moving ram slide forward against stop. Use hydraulic feed lever according to specifications to bring stock to length.
2. Center Drill - Move ram slide forward against stop.
3. Rough Drill - Move drill up to stock. Engage power feed. Depth regulated by stop.
4. Ream. Move reamer up to stock. Engage power feed. Depth regulated by stop.

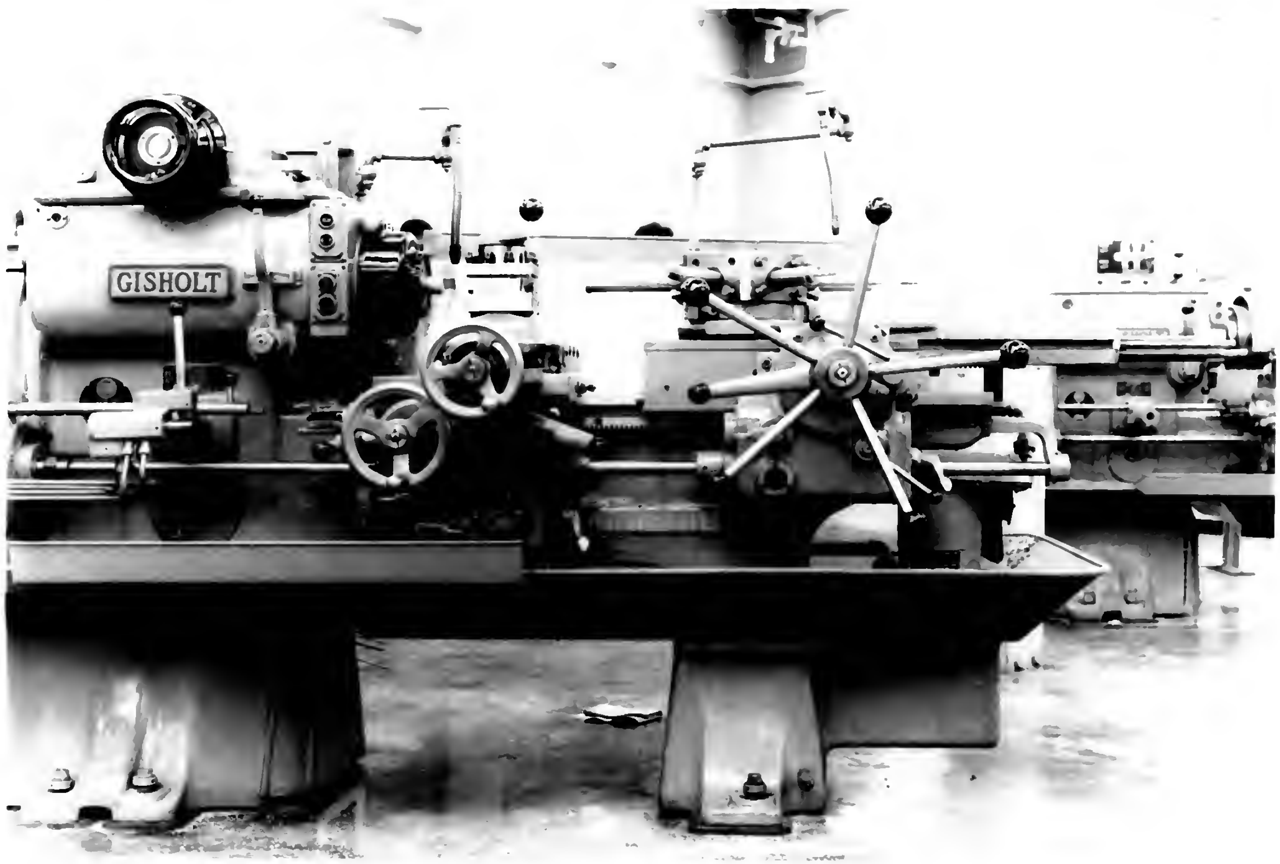
Cross Slide:

1. Rough turn O.D. Set index stop to #1. Set micrometer dial to #1 and then engage longitudinal power feed lever.
2. Finish turn O.D. - Retain index stop #1, set micrometer dial to #2, then engage longitudinal power feed lever.
3. Form 0.625 O.D. - Set index stop #2, lock apron against stop. Turn tool into the work by handwheel one full turn past dial 3 to dial 3.
4. Chamfer - Set index stop #3, operate cut off tool 1/8 inch into work, then back slide so that chamfer tool engages work up to dial 4.
5. Cut-off - Retain stop #3, use lateral handwheel, run tool up to work, then engage lateral power feed, continue

power feed until piece is severed from bar and bar face is completely machined.

Note: In this particular job, the first operations under both the hexagonal turret and the cross slide were omitted to cut down the time.

APPENDIX B



MACHINE CONTROLS

DESCRIPTION OF MACHINE CONTROLS AND DIALS

FOR A

GISHOLT NO. 4 RAM TYPE UNIVERSAL TURRET LATHE

Controls used in this particular job:

A. Spoked Handwheel

Rotates freely in either direction. Used to advance, retract and index turret.
Clockwise - Retracts, unlocks and indexes turret.
Counter-clockwise - Advances and locks turret.
Touch Stimuli:
Advancing.
(1) Vibration and force of initial contact of tool with work.
(2) Vibration of cutting action and reaction force.
(3) Vibration of contact of turret ram with stop screws and reaction force.
Retracting.
(1) Vibration of contact and action of unclamping mechanism and reaction force.
(2) Vibration of contact and action of turret indexing mechanism reaction force.
(3) Vibration of contact of turret ram with back stop and reaction force.

B. Square Turret Lateral Feed Handwheel and Crank

Rotates freely in either direction. Used to advance and retract the square turret (i.e., cross feed).
Clockwise - advance.
Counter-Clockwise - retract.
Touch Stimuli:
Advancing.
(1) Vibration of initial contact of tool with work.
(2) Vibration of cutting action.

C. Lateral Feed Micrometer Dial

Dial turns with lateral feed handwheel. Used to indicate accurately the depth of lateral feed of the tool. Dial is graduated in 0.001 in. and marked every 0.010 in. Numbered clips are provided on the dial to indicate depth settings. The dial is positioned relative to a fixed index at the top of the dial.
Visual Stimuli:
(1) Position of dial and clips relative to fixed index.
(2) Movement of dial and clips relative to fixed index.

D. <u>Square Turret Longitudinal Feed Handwheel and Crank</u>

Rotates freely in either direction. Used to traverse the side carriage right and left (i.e., feed longitudinally in and out).
    Clockwise - traverse right.
    Counter-clockwise - traverse left.
Touch Stimuli:
    Left Traverse.
        (1) Vibration of initial contact of tool with work.
        (2) Vibration of cutting action.
        (3) Contact of apron with stop.

E. <u>Side Carriage Feed Selector Lever</u>

Moves up and down through a limited arc with positive stops at both ends. Has four positions with a detent for each position. These detents are not readily felt. Used to set the power feed rate for the side carriage either for lateral feed, longitudinal feed or both.
Touch Stimuli:
    (a) Positive stops at ends of arc.
    (b) Detent action.
    (c) Meshing action of gears.

F. <u>Side Carriage Feed Selector Dial</u>

Dial made in form of an arc and is integral with the Feed Selector Lever with which it moves. Used to select side carriage power feed. Eight (8) feeds can be selected, four (4) coarse (red) and four (4) fine (black). Numbers are arranged in pairs. Dial is positioned relative to a fixed index above lever axis of rotation.
Visual Stimuli:
    (1) Numbers indicating feed selections.
    (2) Red and Black colors corresponding to coarse and fine feed.
    (3) Position of dial relative to the fixed pointer.
    (4) Movement of dial relative to fixed pointer.

G. <u>Side Carriage Coarse-Fine Feed Selector</u>

A small finger operated lever which moves quite easily when gears are meshed. Moves through a 180 deg. arc with positive stops at both ends. Has two positions.
    "Coarse" - right.
    "Fine" - left
"Coarse" and "fine" markers are attached to the lever and indicate setting when lever is in final position.
Touch Stimuli:
    (1) Meshing of gears.
    (2) Lever against positive stop.

Visual Stimuli:
(1) "Coarse"
(2) "Fine"

H. Square Turret Lateral Feed Engaging Lever

Moves up and down through a small arc between two positions. Spring loaded down against a positive stop. Held in up position by a spring loaded plunger. Lever handle rotates down to retract plunger. Used to engage and disengage lateral power feed clutch.
Up - engage.
Down - disengage.
Touch Stimuli:
(1) Upper positive stop and vibration of plunger action.
(2) Spring loaded movement of lever when rotation of handle retracts plunger.
(3) Bottom positive stop.

I. Side Carriage Longitudinal Feed Engaging Lever

Action identical to Lateral Feed Engaging Lever, except that action of Apron Stop Roll (Indexing Stop) trips out power feed. Used to engage and disengage longitudinal power feed clutch.

J. Side Carriage Indexing Stop

Rotates through 360 deg. Has six (6) positions, each marked with a small number stamped in the metal. A knurled ring around the stop roll facilitates rotation of the stop. All six positions have a detent for final positioning. The stop in the top position is the one that functions; there is no fixed index relative to which the stops are positioned. Used to trip the longitudinal power feed accurately and also as a location for cross slide movement.
Touch Stimuli:
(1) Detent Action.
Visual Stimuli:
(1) "1", "2", -------, or "6".
(2) Position and movement of a particular number relative to top of stop roll.

K. Square Turret Indexing Lever

A ratchet type lever. Rotates in and out through approximately 180 deg. each way. Used to lock and unlock and index the turret.
Touch Stimuli:
Moving in.
(1) Release of pressure and force when turret unlocks.
(2) Vibration and force of contact of ratchet with indexing mechanism.
(3) Force of positive stop when turret locates in next position.

Moving out.
(1) Vibration of action of ratchet mechanism.
(2) Increased pressure and force when turret is locked in position (a binding type of action).

L. Carriage Binder

Rotates through about a 60 deg. horizontal arc. Has two positions, in and out. Used to lock (bind) the side carriage in a specific position.

In - binds carriage.

Out - releases carriage.

Touch Stimuli:

(1) Moving in - Increase of pressure and force due to binding action.

(2) Moving out - Decrease of pressure and force when carriage is released.

Controls Not Used in Particular Job

1. RPM Selector Dial and Pointer.
2. RPM Selector Handwheel.
3. Cutting Speed Selector Dial.
4. Workpiece Diameter Dial.
5. Cutting Speed Selector Ring.
6. Speed Trip Lever.
7. Direct or Pre-Set Selector Lever.
8. Power Motor Control Push Button.
9. Motor Speed Selector.
10. Coolant Switch.
11. Spindle Clutch Lever.
12. Side Carriage Stop Bar Lever.
13. Chuck and Bar Feed Control Lever.
14. Hand Oil Pump Lever.
15. Side Carriage Forward-Reverse Power Feed Selector Lever.
16. Hexagonal Turret Power Feed Trip Lever.
17. Hexagonal Turret Feed Engaging Lever.
18. Hexagonal Turret Feed Selector Dial.
19. Hexagonal Turret Feed Selector Lever.
20. Hand Oil Pump Lever.
21. Hexagonal Turret Stop Screws.

APPENDIX C

VISUAL ACTIVITY ANALYSIS SHEET

DATE FILMED 5 April 1952
ANALYST Ostrom
DATE 19 April 1952

OPERATOR Smith
MACHINE #4 Gisholt
PART Gear Blank

SHEET 1st OF 1

FACE CAMERA		SIDE CAMERA		CUM TIME	VISUAL ACTIVITY			
FRAME	TIME	FRAME	TIME		SYM	OBJECT	STIMULUS	PURPOSE
824	0	180	0	4	CL	None	Clapping boards	Protect Eyes
828	4			5	W	None	None	None
833	9			1	CL	None	Internal	Lubricate Cornea
834	10			1	M			To Clapboards
835	11			3	L	Clapboards	Location & Movement	Determine when area is Clear for Other Activity
838	14			1	M			
839	15			6	L	Spoke of Handwheel	Location	Reference for Movement of Hand
845	21	195	15	3	M			To Workpiece
848	24			40	MV	Advancing Turret	Movement and Distance from Stock	Observe Progress of Turret Advance
881	64			4	P	Center Drill	Movement and Distance from Stock	Regulate Advance of Tool to Work
885	68		61*	22	C	Cutting Action	Size, Shape and Rate of Movement of Chip Relative to Tool. Also, Coolant Flow.	Determine the Momentary Condition and Progress of the Cutting Action
903	90		79*	19	MV	Retracting Turret	Movement	Observe Progress of Turret Retract

*Time cutting action commences or is completed. Time determined from hand motions. Movements of LOS not detectable here.

APPENDIX D

MANIPULATIVE AND TACTILE ACTIVITY ANALYSIS SHEET

DATE FILMED 5 April 1952
ANALYST Ostrom
DATE 19 April 1952

OPERATOR Smith
MACHINE #4 Gisholt
PART Gear Blank

Left Hand
SHEET 1 OF 1

FRAME	SUB. TIME	CUM. TIME	CORR. TIME	MANIPULATIVE ACTIVITY SYM	MANIPULATIVE ACTIVITY OBJECT	MANIPULATIVE ACTIVITY DESCRIPTION	MACHINE DESCRIPTION	TACTILE ACTIVITY SYM	TACTILE ACTIVITY OBJECT	TACTILE ACTIVITY STIMULUS	TACTILE ACTIVITY PURPOSE
21057	0	58	0	UD				I	None	None	None
108	51	5	58	TE		To Spoked Hand-Wheel.		I	None	None	None
112	55	2	63	G	Spoked Handwheel			GC	Spoke	Contract Slip Force	Gain Control
114	57	5	65	U	Spoked Handwheel	Rotate C-C Slow-ly	Advance Center Drill to Work	GC T	Initial Con-tact with Work	Vibration & Force	Determine In-itiation of Cutting Action
118	61	20	70	U	Spoked Handwheel	Rotate C.C.	Feed Center Drill	GC C	Cutting Action & Contact of Ram with Stop	Vibration & Force	Determine Con-dition & Progress
136	79	7	90	U	Spoked Handwheel	Rotate C. Rapid-ly	Retract Turret	GC	Spoke	Contact Slip Force	Maintain Control
142	85	6	97	RL TE		To Balancing Position		I	None	None	None
147	90	6	103	U				I	None	None	None
152	95	7	109	TE		To Drill		I	None	None	None
158	101	3	116	G	Drill			GC	Drill	(63)	(63)
161	104	17	119	U	Drill	Steady Index-ing Turret		GC T	Indexing Turret Lo-cating Pin Entering Bushing	Movement & Force Vibration	Determine Termination of Turret Indexing

APPENDIX E

JOB SOUND DATA SHEET

DATE May 15, 1952 — MACHINE Gisholt #4 Ram Type Turret Lathe — SHEET 1 OF 2

RECORDER Ostrom — OPERATOR Smith

ASSOCIATED ACTIVITY	SOURCE	TIME KEY	CHARACTERISTICS	SIGNIFICANCE
Clockwise Rotation of spoked Handwheel.	Action of Indexing Mechanism	Initiation of Turret Indexing	Loud thud	Hexagonal turret has commenced to index
Clockwise rotation of spoked handwheel	Locating pin entering turret bushing	Completion of turret indexing	Click	Hexagonal turret has completed indexing
Counter-clockwise rotation of spoked handwheel	Action of Indexing Mechanism	Turret 1/3 Advanced	Click	Hexagonal turret can be indexed again
Pulling up Square Turret Feed Engaging Lever	Locking Plunger Entering Catch	Top of Movement of Lever	Low Click	Power Feed has been Engaged
Pushing down Square Turret Feed Engaging Lever	Contact of Lever with Positive Stop	End of Downward Movement of Plunger	Thud	Power Feed has been Disengaged
Inward Movement of Square Turret Indexing Lever	Locating Pin Entering Turret Bushing	End of Inward Movement	Click	Square Turret Indexing Completed
Outward Movement of Square Turret Indexing Lever	Action of Indexing Mechanism	Lever Parallel to Machine Axis	Click	Square Turret can be Indexed Again

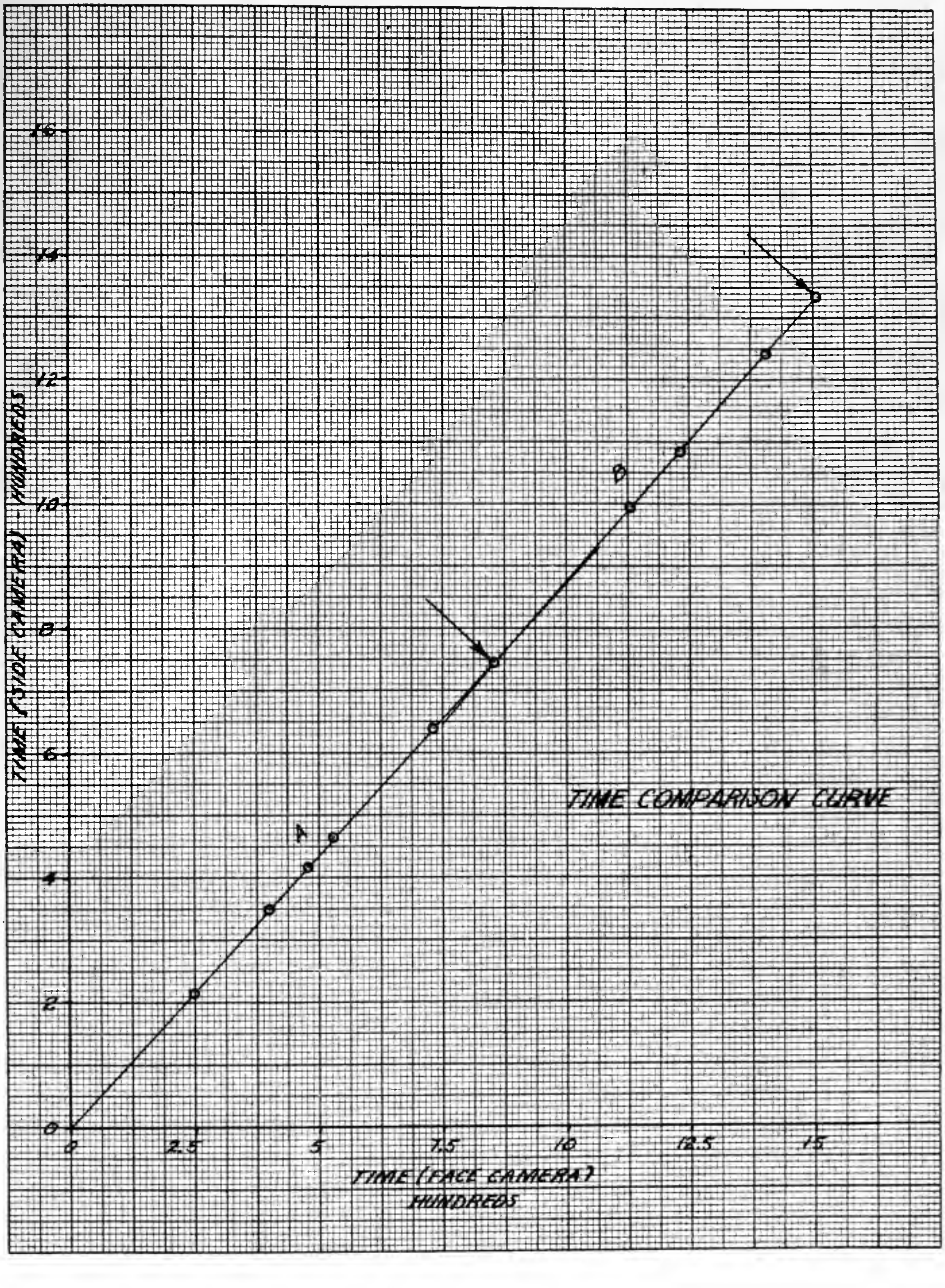
JOB SOUND DATA SHEET

DATE MACHINE SHEET 2 OF 2

RECORDER OPERATOR

ASSOCIATED ACTIVITY	SOURCE	TIME KEY	CHARACTERISTICS	SIGNIFICANCE
	Cutting Action	Activity Associated with Initiation and Termination of Cutting Action	Crackle	Cutting action in Progress
	Machine Motor	Background Noise	Hum	Machine Ready for Operation

APPENDIX F



TIME (SIDE CAMERA) - HUNDREDS
0
2
4
6
8
10
12
14
16
0
2.5
5
7.5
10
12.5
15
TIME (FACE CAMERA) HUNDREDS
A
B
TIME COMPARISON CURVE

TIME DATA CORRECTIONS

The face camera times were assumed to be correct and the side camera time values were corrected to correspond to them.

Referring to the graph, it will be seen to be divided into two linear segments A and B.

Letting:

x = time (face camera)

y = time (side camera)

k = conversion factor for segment A or B.

$$x = ky$$

Average values of $k_A = 1.145$

$k_B = 1.138$

APPENDIX G

SUMMARY OF THE CLASSIFICATIONS OF ACTIVITY

CLASSIFICATIONS OF VISUAL ACTIVITY

(M) Movement of the LOS

(CL) Closed

(W) Wander

(MV) Movement

(CR) Color

(SF) Surface Finish

(SH) Shape

(SZ) Size

(L) Location

(P) Position

(IT) Intensity

(S) Search

(ID) Identity

(T) Termination

(MR) Monitor

(C) Control

(R) Read

(MM) Mathemation

(CT) Count

CLASSIFICATIONS OF AUDITORY ACTIVITY

(LD) Loudness

(PC) Pitch

(TB) Timbre

(L) Location

(MV) Movement

(ID) Identity

(S) Search

(T) Termination

(MR) Monitor

(C) Control

(SP) Speech

CLASSIFICATIONS OF TACTILE ACTIVITY

(V) Vibration

(TR) Temperature

(L) Location

(WT) Weight

(GC) Grasp Control

(SF) Surface Finish

(P) Position

(SH) Shape

(SZ) Size

(S) Search

(ID) Identity

(CT) Count

(T) Termination

(MR) Monitor

(C) Control

(I) Idle

TOTAL ACTIVITY CHART

SHEET 1 OF 13

TIME	VISUAL SYMBOL	VISUAL OBJECT	VISUAL STIMULUS	AUDITORY SYMBOL	AUDITORY SOURCE	AUDITORY STIMULUS	TACTILE LEFT HAND SYMBOL	TACTILE LEFT HAND OBJECT	TACTILE LEFT HAND STIMULUS	TACTILE RIGHT HAND SYMBOL	TACTILE RIGHT HAND OBJECT	TACTILE RIGHT HAND STIMULUS	MEANING SYMBOL	MEANING CONDITION	MEANING ACTION	MANIPULATIVE LEFT HAND SYMBOL	MANIPULATIVE LEFT HAND OBJECT	MANIPULATIVE LEFT HAND DESCRIPTION	MANIPULATIVE RIGHT HAND SYMBOL	MANIPULATIVE RIGHT HAND OBJECT	MANIPULATIVE RIGHT HAND DESCRIPTION	MACHINE DESCRIPTION
	CL	NONE	CLAPPING BOARDS				I	NONE	NONE	I						UD			UD			
	W	NONE	NONE																			
10	CL M	NONE	INTERNAL																			
	L	CLAPBOARDS	LOCATION AND MOVEMENT																			
	M																					
	L	SPOKE OF HANDWHEEL	LOCATION										V	WORK AREA CLEAR	BEGIN WORK, CENTER DRILL							
20	M																		TE		TO SPOKED HANDWHEEL	
	MV	ADVANCING TURRET	MOVEMENT AND DISTANCE FROM STOCK																			
30																						
										GC		SLIP, CONTACT, FORCE							G	SPOKED HANDWHEEL		
40																			U	SPOKED HANDWHEEL	ROTATE C-C RAPIDLY	ADVANCE TURRET
50																						
60										GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE	V	TOOL APPROACHING WORK	SLOW DOWN ADVANCE	TE		TO SPOKED HANDWHEEL	U	SPOKED HANDWHEEL	ROTATE C-C SLOWLY	ADVANCE CENTER DRILL TO WORK
							GC		SLIP, CONTACT, FORCE							G	SPOKED HANDWHEEL					
	P	CENTER DRILL	MOVEMENT AND DISTANCE FROM STOCK																			
							GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE							U	SPOKED HANDWHEEL	ROTATE C-C SLOWLY				
	C	CUTTING ACTION	SIZE, SHAPE, AND RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO, COOLANT FLOW																			
70							GC C	CUTTING ACTION AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE	GC C	CUTTING ACTION AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE	T	CUTTING ACTION HAS BEGUN	FEED CENTER DRILL	U	SPOKED HANDWHEEL	ROTATE C-C	U	SPOKED HANDWHEEL	ROTATE C-C SLOWLY	FEED CENTER DRILL
80																						
90	MV	RETRACTING TURRET	MOVEMENT				GC		SLIP, CONTACT, FORCE	GC		SLIP, CONTACT, FORCE	T	CENTER DRILLING COMPLETED	RETRACT CENTER DRILL	U	SPOKED HANDWHEEL	ROTATE C. RAPIDLY	U	SPOKED HANDWHEEL	ROTATE C. RAPIDLY	RETRACT TURRET
							I	NONE	NONE							RL TE		TO BALANCING POSITION				
100																UD						
110	L	DRILL	LOCATION. ALSO MOVEMENT OF HAND													TE		TO DRILL				
	MV	INDEXING TURRET	ROTATION				GC		SLIP, CONTACT, FORCE							G	DRILL					
120				T	ACTION OF INDEXING MECHANISM	LOUD THUD	GC T	INDEXING TURRET TURRET LOCATING PIN ENTERING BUSHING	MOVEMENT & FORCE VIBRATION	GC T	ACTION OF INDEXING MECHANISM AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE	T A	RETRACT COMPLETED	INDEX TURRET	U	DRILL	STEADY INDEXING TURRET	U	SPOKED HANDWHEEL	ROTATE CLOCKWISE	INDEX TURRET
130	MV	ADVANCING TURRET	MOVEMENT AND DISTANCE FROM STOCK	T	LOCATING PIN ENTERING TURRET BUSHING	CLICK	GC		SLIP, CONTACT, FORCE	GC		SLIP, CONTACT, FORCE	T V A	TURRET INDEXED	ADVANCE TURRET				U	SPOKED HANDWHEEL	ROTATE C-C RAPIDLY	ADVANCE TURRET
							I	NONE	NONE							RL TE		TO BALANCING POSITION				
140																						
150																UD						

TOTAL ACTIVITY CHART

SHEET 2 OF 13

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE	TIME
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND				
	SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION	
160																							160
										I	NONE	NONE							RL TE		TO ANOTHER SPOKE		
							L	SPOKE	SLIP CONTACT							G*	SPOKE	CONTACT SPOKE					
										GC	SPOKE	SLIP CONTACT FORCE	V	DRILL APPROACHING WORK	SLOW DOWN ADVANCE				G	SPOKE			
170																							170
	P	DRILL	MOVEMENT & DISTANCE FROM STOCK				I	NONE	NONE	GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE				RL UD		FOR NEXT SPOKE	U	SPOKE	ROTATE C-C SLOWLY	ADVANCE DRILL TO STOCK	
	C	CUTTING ACTION	SIZE, SHAPE AND RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO, COOLANT FLOW	MR	CUTTING ACTION	CRACKLE				GC C	CUTTINGACTION AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE	T	DRILLING HAS BEGUN	FEED DRILL				U	SPOKE	ROTATE C-C	FEED ROUGH DRILL	
							GC C	CUTTING ACTION AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE							G U	SPOKE	ROTATE COUNTER-CLOCKWISE					
180																							180
190																							190
200																							200
210																							210
220																							220
230																							230
	MV	RETRACTING TURRET	MOVEMENT							GC	SPOKE	SLIP, CONTACT FORCE	T	DRILLING COMPLETED	RETRACT TURRET				U	SPOKE	ROTATE C-C RAPIDLY	RETRACT TURRET	
							I	NONE	NONE							RE TE		TO BALANCING POSITION					
240																							240
																UD							
	L	REAMER	LOCATION OF REAMER AND MOVEMENT OF HAND																				
										I	NONE	NONE							RL TE		TO ANOTHER SPOKE		
250																							250
										GC	SPOKE	SLIP CONTACT FORCE				TE		TO REAMER	G*	SPOKE			
	MV	RETRACTING TURRET	MOVEMENT				GC	REAMER	SLIP CONTACT FORCE							G	REAMER						
	MV	INDEXING TURRET	ROTATION	T	ACTION OF INDEXING MECHANISM	LOUD THUD	GC T	INDEXING TURRET TURRET LOCATING PIN ENTERING BUSHING	MOVEMENT AND FORCE VIBRATION	GC T	ACTION OF INDEXING MECHANISM AND CONTACT OF RAM WITH STOP	VIBRATION AND FORCE	T A	RETRACT COMPLETED	INDEX TURRET	U	REAMER	STEADY INDEXING TURRET	U	SPOKE	ROTATE C	INDEX TURRET	
260																							260
	MV	ADVANCING TURRET	MOVEMENT AND DISTANCE FROM STOCK	T	LOCATING PIN ENTERING TURRET BUSHING	CLICK				GC	SPOKE	SLIP, CONTACT FORCE	T V A	TURRET INDEXED	ADVANCE TURRET				U	SPOKE	ROTATE C-C RAPIDLY	ADVANCE TURRET	
270																							270
							I	NONE	NONE							RL TE		TO SPOKED HANDWHEEL					
										I	NONE	NONE							RL TE		TO ANOTHER SPOKE		
										GC	SPOKE	SLIP CONTACT FORCE							G	SPOKE			
																			U	SPOKE	ROTATE C-C RAPIDLY		
280																							280
290																							290
							L	SPOKE	SLIP, CONTACT							G*	SPOKE	CONTACT SPOKE					
																RL UD		FOR NEXT SPOKE					
							I	NONE	NONE														
																G*	SPOKE	CONTACT SPOKE					

TOTAL ACTIVITY CHART

SHEET 3 OF 13

VISUAL

TIME	SYMBOL	OBJECT	STIMULUS
	P	REAMER	MOVEMENT OF REAMER & DISTANCE FROM STOCK
310	C	CUTTING ACTION	COOLANT FLOW
360	MV	RETRACTING TURRET	MOVEMENT
	MV	INDEXING TURRET	ROTATION
400	M		
	L	LATERAL FEED HANDWHEEL CRANK	LOCATION
	M		
410	P	TURNING TOOL	MOVEMENT AND DISTANCE FROM WORK
	M		
	R P	"I" ON INDEXING STOP	
450	M		

AUDITORY

SYMBOL	SOURCE	STIMULUS
MR	CUTTING ACTION	CRACKLE
T	ACTION OF INDEXING MECHANISM	LOUD THUD
T	LOCATING PIN ENTERING TURRET BUSHING	CLICK

TACTILE

LEFT HAND

SYMBOL	OBJECT	STIMULUS
I	NONE	NONE
GC	SPOKE	CONTACT, SLIP FORCE
GC C	CUTTING ACTION & CONTACT OF RAM WITH STOP	VIBRATION AND FORCE
GC	SPOKE	CONTACT, SLIP, FORCE
I	NONE	NONE
GC	LONGITUDINAL FEED HANDWHEEL CRANK	CONTACT SLIP FORCE
I	NONE	NONE

RIGHT HAND

SYMBOL	OBJECT	STIMULUS
GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE
GC C	CUTTING ACTION CONTACT OF RAM WITH STOP	VIBRATION AND FORCE
GC	SPOKE	SLIP CONTACT FORCE
I	NONE	NONE
GC	SPOKE	SLIP CONTACT FORCE
GC T	ACTION OF INDEXING MECHANISM CONTACT OF RAM WITH STOP	VIBRATION FORCE
GC	SPOKE	SLIP CONTACT FORCE
I	NONE	NONE
GC	SQ. TURRET LATERAL FEED HANDWHEEL CRANK	SLIP CONTACT FORCE
I	NONE	NONE
GC	LATERAL FEED HANDWHEEL	SLIP CONTACT FORCE

MEANING

SYMBOL	CONDITION	ACTION
Y	TOOL APPROACHING WORK	SLOW DOWN
T	REAMING HAS BEGUN	FEED REAMER
T	REAMING COMPLETED	RETRACT TURRET
A T	RETRACT COMPLETED	INDEX TURRET
A T	TURRET INDEXED	COMMENCE SQUARE TURRET OPERATIONS

MANIPULATIVE

LEFT HAND

SYMBOL	OBJECT	DESCRIPTION
RL UD		
G	SPOKE	
	SPOKE	ROTATE SLOWLY C-C.
U	SPOKE	ROTATE RAPIDLY C.
RL TE		TO BALANCING POSITION
UD		
TE		TO SQUARE TURRET LONGITUDINAL FEED HANDWHEEL CRANK
G*	LONGITUDINAL FEED HANDWHEEL CRANK	ROTATE C-C
RL* TE		TO LATERAL FEED HANDWHEEL

RIGHT HAND

SYMBOL	OBJECT	DESCRIPTION
U	SPOKE	ROTATE SLOWLY C-C.
U	SPOKE	ROTATE SLOWLY C.-C.
U	SPOKE	ROTATE RAPIDLY C.
RL TE	SPOKE	TO ANOTHER SPOKE
G U	SPOKE	ROTATE RAPIDLY C
U	SPOKE	ROTATE C.
RL	SPOKE	
TE		SQ. TURRET LATERAL FEED HANDWHEEL CRANK
G	SQ. TURRET LATERAL FEED HANDWHEEL CRANK	
U	SQ. TURRET LATERAL FEED HANDWHEEL CRANK	ROTATE CLOCKWISE RAPIDLY
RL TE		SEE NOTE BELOW
G	LATERAL FEED HANDWHEEL	

MACHINE

DESCRIPTION
ADVANCE REAMER TO STOCK
FEED REAMER
RETRACT TURRET
RETRACT TURRET
INDEX TURRET
ADVANCING TURNING TOOL TO WORK
TRAVERSE TURNING TOOL TO WORK

TIME: 310, 320, 330, 340, 350, 360, 370, 380, 390, 400, 410, 420, 430, 440, 450

* HAND PARTIALLY OBSCURED

TO SQ. TURRET LATERAL FEED HANDWHEEL CRANK

TOTAL ACTIVITY CHART

SHEET 4 OF 13

VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE
						LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND			
SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION
R P	"Z" CLIP AND DIAL SCRIBE	MOVEMENT AND DISTANCE FROM FIXED INDEX																U	LATERAL FEED HANDWHEEL	ROTATE CLOCKWISE	SET MICROMETER DIAL TO "Z"
						GC	LATERAL FEED HANDWHEEL	CONTACT SLIP FORCE							G U	LATERAL FEED HANDWHEEL	ROTATE CLOCKWISE				SET MICROMETER DIAL TO "Z"
									I	NONE	NONE							RL TE		TO RELAXED POSITION	
M																					
P	TURNING TOOL	TRAVERSE MOVEMENT AND DISTANCE FROM WORK				I	NONE	NONE							RL TE		TO LONGITUDINAL FEED HANDWHEEL				
																		UD			
M																					
L	LONGITUDINAL FEED ENGAGING LEVER KNOB	LOCATION				GC P	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION FORCE							G U	LONGITUDINAL FEED HAND-WHEEL	ROTATE C-C				TRAVERSE TURNING TOOL TO WORK
						I	NONE	NONE				T	TOOL IN CONTACT WITH WORK	ENGAGE POWER FEED	RL TE		TO LONGITUDINAL FEED ENGAGING LEVER				
															G U	LONGITUDINAL FEED ENGAGING LEVER	PULL UP	TE		TO FEED SELECTOR LEVER	ENGAGE LONGITUDINAL POWER FEED
M						GC P	PLUNGER ACTION AND POSITIVE STOP	VIBRATION AND FORCE													
L	FEED SELECTOR LEVER KNOB	LOCATION	T	LOCKING PLUNGER ENTERING CATCH	LOW CLICK	I	NONE	NONE				A T	POWER FEED HAS ENGAGED	SET FEED	RL TE		TO RELAXED POSITION				
									GC	FEED SELECTOR LEVER	SLIP, CONTACT FORCE							G	FEED SELECTOR LEVER		
															UD						
P	FEED SELECTOR LEVER	MOVEMENT AND FINAL POSITION							GC P	DETENTS POSITIVE STOP	FORCE MOVEMENT							U	FEED SELECTOR LEVER	PUSH DOWN RAPIDLY	SET "FEED"
									I	NONE	NONE	T	FEED SET	MONITOR CUTTING ACTION				RL TE		TO RELAXED POSITION	
M																					
MR	CUTTING ACTION	SIZE, SHAPE & RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO, THE RESULTING SHAPE & SURFACE FINISH OF WORKPIECE AND COOLANT FLOW																			
																		UD			
L	COOLANT NOZZLE	LOCATION													TE		TO COOLANT NOZZLE				
P	COOLANT FLOW	FLOW OF COOLANT RELATIVE TO TOOL				GC	COOLANT NOZZLE	CONTACT SLIP FORCE							G U	COOLANT NOZZLE	ADJUST NOZZLE POSITION FOR PROPER COOLANT FLOW				
MR	CUTTING ACTION	SIZE, SHAPE AND RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO, THE RESULTING SHAPE AND SURFACE FINISH OF WORKPIECE AND COOLANT FLOW				I	NONE	NONE							RL TE		TO RELAXED POSITION				
M																					
															UD		FOR MACHINE				
L	LONGITUDINAL FEED HANDWHEEL CRANK	LOCATION																			

TIME: 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600

TOTAL ACTIVITY CHART

TIME: 610, 620, 630, 640, 650, 660, 670, 680, 690, 700, 710, 720, 730, 740, 750

VISUAL Symbol	VISUAL Object	VISUAL Stimulus	AUDITORY Symbol	AUDITORY Source	AUDITORY Stimulus	TACTILE Left Hand Symbol	TACTILE Left Hand Object	TACTILE Left Hand Stimulus	TACTILE Right Hand Symbol	TACTILE Right Hand Object	TACTILE Right Hand Stimulus	MEANING Symbol	MEANING Condition	MEANING Action	MANIPULATIVE Left Hand Symbol	MANIPULATIVE Left Hand Object	MANIPULATIVE Left Hand Description	MANIPULATIVE Right Hand Symbol	MANIPULATIVE Right Hand Object	MANIPULATIVE Right Hand Description	MACHINE Description
															TE		LONGITUDINAL FEED HANDWHEEL CRANK				
						L*	LONGITUDINAL FEED HANDWHEEL CRANK	CONTACT SLIP							G*	LONGITUDINAL FEED HANDWHEEL CRANK *					
M																					
MR	CUTTING ACTION	SIZE, SHAPE AND RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO THE RESULTING SHAPE AND SURFACE FINISH OF WORK-PIECE AND COOLANT FLOW																			
			T	CONTACT OF FEED ENGAGING LEVER WITH POSITIVE STOP	THUD	GC	CONTACT OF CARRIAGE WITH STOP	VIBRATION FORCE				A	POWER FEED COMPLETED	INDEX TURRET	C* U	HANDWHEEL CRANK	ROTATE C-C.				
P	TURNING TOOL	RIGHT TRAVERSE MOVEMENT AND POSITION RELATIVE TO WORK				GC	HANDWHEEL CRANK	SLIP CONTACT FORCE							U	HANDWHEEL CRANK	ROTATE CLOCKWISE	TE		SQUARE TURRET INDEXING LEVER	TRAVERSE TURRET
									L	TURRET INDEXING LEVER	SLIP CONTACT							G*	TURRET INDEXING LEVER		
M									GC	TURRET INDEXING LEVER	SLIP, CONTACT, FORCE							G	TURRET INDEXING LEVER		
MV	SQUARE TURRET	ROTATION				I	NONE	NONE	GC P	LOCKING & RATCHET MECHANISM AND POSITIVE STOP	VARIATIONS OF FORCE, CONTACT AND MOVEMENT				RL TE		TO SQUARE TURRET	U	TURRET INDEXING LEVER	PUSH IN	INDEX TURRET
						GC	SQUARE TURRET	SLIP CONTACT FORCE							G. U	SQUARE TURRET	HELP INDEX TURRET				
			T	LOCATING PIN ENTERING TURRET BUSHING	CLICK				GC P	RATCHET AND LOCKING MECHANISMS	VIBRATION AND FORCE	A T	TURRET INDEXED	LOCK TURRET				U	TURRET INDEXING LEVER	PULL BACK	LOCK RATCHET AND LOCK TURRET
									GC	TURRET INDEXING LEVER	SLIP CONTACT FORCE	T	TURRET LOCKED	SET INDEXING STOP				U	TURRET INDEXING LEVER	HOLD ON TO BALANCE BODY	
M						I	NONE	NONE							RL TE		TO INDEXING STOP				
L	INDEXING STOP	LOCATION																			

* HAND PARTIALLY OBSCURED

★ CONTACT GRASP

TOTAL ACTIVITY CHART

SHEET 6 OF 13

Time scale (both margins): 760, 770, 780, 790, 800, 810, 820, 830, 840, 850, 860, 870, 880, 890, 900

VISUAL

SYMBOL	OBJECT	STIMULUS
R, P	"2"	MOVEMENT & FINAL POSITION AT TOP
M		
P	FORM TOOL	MOVEMENT AND POSITION RELATIVE TO WORK
M		
L	CARRIAGE BINDER KNOB	LOCATION
P	CARRIAGE BINDER	MOVEMENT & FINAL POSITION
M		
P	FORM TOOL	MOVEMENT AND POSITION RELATIVE TO WORK
M		
L	COARSE-FINE FEED SELECTOR	LOCATION
P	COARSE-FINE FEED SELECTOR	MOVEMENT AND FINAL POSITION
M		
L	LATERAL FEED ENGAGING LEVER	LOCATION
M		
L	COOLANT NOZZLE	LOCATION
P	COOLANT FLOW	POSITION RELATIVE TO TOOL

AUDITORY

SYMBOL	SOURCE	STIMULUS
T	LOCKING PLUNGER ENTERING CATCH	LOW CLICK

TACTILE

LEFT HAND

SYMBOL	OBJECT	STIMULUS
GC	INDEXING STOP	SLIP CONTACT FORCE
GC	DETENT ACTION	VARIATION OF FORCE AND MOVEMENT
I	NONE	NONE
GC T	CONTACT OF CARRIAGE WITH STOP	VIBRATION FORCE
GC	FEED HANDWHEEL CRANK	CONTACT FORCE
I	NONE	NONE

RIGHT HAND

SYMBOL	OBJECT	STIMULUS
I	NONE	NONE
L	LATERAL FEED HANDWHEEL CRANK	SLIP CONTACT
GC	LATERAL FEED HANDWHEEL CRANK	SLIP CONTACT FORCE
I	NONE	NONE
GC P	BINDING ACTION	INCREASING PRESSURE AND FORCE
I	NONE	NONE
L	HANDWHEEL CRANK	SLIP CONTACT
GC	HANDWHEEL CRANK	SLIP CONTACT, FORCE
GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE
I	NONE	NONE
GC	COARSE-FINE FEED SELECTOR	SLIP CONTACT FORCE
GC P	MESHING ACTION & POSITIVE STOP	VIBRATION, FORCE, MOVEMENT
I	NONE	NONE
GC P	PLUNGER ACTION & POSITIVE STOP	VIBRATION & FORCE
I	NONE	NONE
GC	COOLANT NOZZLE	SLIP CONTACT, FORCE

MEANING

SYMBOL	CONDITION	ACTION
V T	INDEXING STOP SET TO "2"	POSITION CARRIAGE AGAINST STOP
T	CARRIAGE AGAINST STOP	BIND CARRIAGE
T	CARRIAGE BOUND	ADVANCE TOOL TO WORK
T	TOOL IN CONTACT WITH WORK	SET FEED
T	FEED SET	ENGAGE POWER FEED
A	POWER FEED ENGAGED	MONITOR CUTTING ACTION

MANIPULATIVE

LEFT HAND

SYMBOL	OBJECT	DESCRIPTION
G*	INDEXING STOP	
U	INDEXING STOP	ROTATE STOP TO PUT STOP "2" IN TOP POSITION
RL TE	INDEXING STOP	LONGITUDINAL FEED HANDWHEEL CRANK
G U	FEED HANDWHEEL CRANK	ROTATE C-C
U	FEED HANDWHEEL CRANK	APPLY FORCE
RL# UD		

RIGHT HAND

SYMBOL	OBJECT	DESCRIPTION
RL TE		TO LATERAL FEED HANDWHEEL CRANK
G*	LATERAL FEED HANDWHEEL CRANK	
G	LATERAL FEED HANDWHEEL CRANK	
U	LATERAL FEED HANDWHEEL CRANK	ROTATE HANDWHEEL C-C
RL TE		TO CARRIAGE BINDER
G* U	CARRIAGE BINDER	PUSH IN
RL TE		TO LATERAL FEED HANDWHEEL CRANK
G*	HANDWHEEL CRANK	
G	HANDWHEEL CRANK	
U	HANDWHEEL CRANK	ROTATE CLOCKWISE
RL TE		TO COARSE-FINE FEED SELECTOR
G	COARSE-FINE FEED SELECTOR	
U	COARSE-FINE FEED SELECTOR	ROTATE C-C TO LEFT POSITION
RL TE		TO LATERAL FEED ENGAGING LEVER
G, U	FEED ENGAGING LEVER	PULL UP
RL TE		TO COOLANT NOZZLE
G, U	COOLANT NOZZLE	ADJUST NOZZLE TO DIRECT COOLANT ON TOOL

MACHINE

DESCRIPTION
* RETRACT TURRET TRAVERSE CARRIAGE TO LEFT AGAINST STOP
HOLD TURRET AGAINST STOP
BIND CARRIAGE IN TRAVERSE
ADVANCE FORM TOOL TO WORK
SET FEED TO FINE
COMMENCE LATERAL POWER FEED

* CONTACT GRASP
# HAND OBSCURED, ESTIMATED DATA

* TRAVERSE CARRIAGE TO LEFT AGAINST STOP

TOTAL ACTIVITY CHART

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE	TIME
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND				
	SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION	
										I	NONE	NONE							RL TE		TO LATERAL FEED ENGAGING LEVER		
910																							910
	M																						
	L	LATERAL FEED ENGAGING LEVER	LOCATION							GC	FEED ENGAGING LEVER	CONTACT							G*	FEED ENGAGING LEVER	APPLY TOUCH		
920																							920
	M																						
	MV	"3" CLIP	MOVEMENT AND POSITION RELATIVE TO INDEX SCRIBE																				
930																							930
940																							940
950																							950
960																							960
970																							970
980																							980
990																							990
1000																							1000
1010																							1010
1020																							1020
1030																							1030
1040																							1040
1050																							1050

* CONTACT GRASP

TOTAL ACTIVITY CHART

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND			
	SYMBOL	OBECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION
1060																						
1070																						
1080																						
1090																						
1100																						
										I	NONE	NONE							TE		TO STRIKE LEVER KNOB	
1110										P	LEVER ACTION & POS STOP	MOVEMENT & FORCE							G,U	FEED ENGAGE LEVER	STRIKE DOWN	
				T	CONTACT OF LEVER WITH POSITIVE STOP	THUD				I	NONE	NONE	A T	POWER FEED DISENGAGED	FEED BY HAND TO "3"				RL TE		TO LATERAL FEED HAND WHEEL	DISENGAGE POWER FEED
1120	P	3" CLIP	MOVEMENT & DISTANCE FROM FIXED INDEX							GC C	CUTTING ACTION	VIBRATION & FORCE							G U	FEED HAND-WHEEL	ROTATE SLOWLY C	FEED TOOL & SET DIAL TO "3"
							GC C	CUTTING ACTION	VIBRATION & FORCE							G* U	LATERAL FEED HANDWHEEL	ROTATE SLOWLY C				FEED TOOL AND SET DIAL TO "3"
1130										I	NONE	NONE							RL TE		TO LATERAL FEED HANDWHEEL CRANK	
										GC	HANDWHEEL CRANK	SLIP, CONTACT, FORCE							G U	HANDWHEEL CRANK	ROTATE HAND-WHEE C-C	RETRACT TURRET
	M												V	FORM CUT COMPLETED	RETRACT AND FREE CARRIAGE							
							I	NONE	NONE							RL TE		TO LONGITUDINAL FEED HANDWHEEL CRANK				
1140	P	FORM TOOL	MOVEMENT & POSITION RELATIVE TO WORK																			
1150							GC	LONGITUDINAL FEED HANDWHEEL CRANK	SLIP, CONTACT FORCE	I	NONE	NONE				G*	LONGITUDINAL FEED HAND-WHEEL CRANK		RL TE		TO CARRIAGE BINDER	
	M																					
	L	CARRIAGE BINDING LEVER	LOCATION																			
1160	P	CARRIAGE BINDER	MOVEMENT TO FINAL POSITION OF BINDER							GC P	BINDING ACTION	DECREASING PRESSURE & FORCE							G U	CARRIAGE BINDER	PULL OUT	FREE CARRIAGE
										I	NONE	NONE	T	CARRIAGE FREE	INDEX TURRET				RL TE		TO SQUARE TURRET INDEXING LEVER	
	m																					
	P	FORM TOOL	MOVEMENT & POSITION RELATIVE TO WORK							L	TURRET INDEXING LEVER	SLIP, CONTACT				U	LONGITUDINAL FEED HAND-WHEEL CRANK	ROTATE C	G*	TURRET INDEXING LEVER		TRAVERSE TURRET TO RIGHT & CLEAR WORK
1170																						
										GC	TURRET INDEXING LEVER	SLIP, CONTACT FORCE							G	TURRET INDEXING LEVER		
1180	L	SQUARE TURRET	LOCATION				I	NONE	NONE							RL TE		TO INDEXING STOP				
										GC P	LOCKING & RACHET MECH. & POSITIVE STOP	VARIATION OF FORCE, CONTACT & MOVEMENT							U	TURRET INDEXING LEVER	PUSH IN	INDEX TURRET
	MV	SQUARE TURRET	ROTATION				GC	SQUARE TURRET	SLIP, CONTACT FORCE							G U	SQUARE TURRET	HELP INDEX TURRET.				
1190																						
1200				T	LOCATING PIN ENTERING BUSHING	CLICK				GC P	RACHET & COCKING MECHANISMS	VIBRATION & FORCE	A T	TURRET INDEXED	SET INDEXING STOP				U	TURRE LOCKING LEVER	PULL BACK	COCK RACHET & LOCK TURRET

\# HAND OBSCURED, DATA DOUBTFUL   * "Contact" Grasp

TOTAL ACTIVITY CHART

TIME: 1210, 1220, 1230, 1240, 1250, 1260, 1270, 1280, 1290, 1300, 1310, 1320, 1330, 1340, 1350

VISUAL

SYMBOL	OBJECT	STIMULUS
M		
P*	CUTOFF TOOL	POSITION RELATIVE TO WORK
M		
L	INDEXING STOP	LOCATION
R, P	"3" ON INDEXING STOP	MOVEMENT AND DISTANCE FROM TOP
M		
P	CUTOFF TOOL	MOVEMENT AND POSITION RELATIVE TO WORK
M		
L	CARRIAGE BINDER KNOB	LOCATION
P	CARRIAGE BINDER	MOVEMENT AND FINAL POSITION
M		
P	CUTOFF TOOL, WORK, AND COOLANT FLOW	MOVEMENT & POSITION OF TOOL RELATIVE TO WORK & MOVEMENT OF HAND TO COOLANT NOZZLE AND MOVEMENT & FINAL POSITION OF COOLANT STREAM
C	CUTTING ACTION	SIZE, SHAPE & RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO THE RESULTING SHAPE & SURFACE FINISH OF WORKPIECE & COOLANT FLOW

AUDITORY

SYMBOL	SOURCE	STIMULUS

TACTILE

LEFT HAND

SYMBOL	OBJECT	STIMULUS
I	NONE	NONE
GC P	DETENT ACTION	VARIATION OF FORCE AND MOVEMENT
I	NONE	NONE
GC T	CONTACT OF CARRIAGE WITH STOP	VIBRATION FORCE
GC	FEED HANDWHEEL CRANK	CONTACT FORCE
I	NONE	NONE
GC	COOLANT NOZZLE	CONTACT SLIP FORCE
I	NONE	NONE
GC C	CUTTING ACTION	VIBRATION AND FORCE

RIGHT HAND

SYMBOL	OBJECT	STIMULUS
I	NONE	NONE
L	LATERAL FEED HANDWHEEL	CONTACT SLIP
L	HANDWHEEL CRANK	CONTACT SLIP
GC	HANDWHEEL CRANK	CONTACT SLIP FORCE
I	NONE	NONE
GC	CARRIAGE BINDER	CONTACT, SLIP, FORCE
GC P	BINDING ACTION	INCREASING PRESSURE AND FORCE
I	NONE	NONE
GC	LATERAL FEED HANDWHEEL CRANK	CONTACT, SLIP, FORCE
GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE
GC C	CUTTING ACTION	VIBRATION & FORCE

MEANING

SYMBOL	CONDITION	ACTION
V T	INDEXING STOP SET TO "3"	POSITION CARRIAGE AGAINST STOP
T	CARRIAGE AGAINST STOP	BIND CARRIAGE
T	CARRIAGE BOUND	ADVANCE TOOL TO WORK
T	CUTTING ACTION HAS BEGUN	FEED TOOL

MANIPULATIVE

LEFT HAND

SYMBOL	OBJECT	DESCRIPTION
RL TE		TO INDEXING STOP
G, U	INDEXING STOP	ROTATE STOP TO PUT STOP "3" IN POSITION
RL TE		TO LONGITUDINAL FEED HANDWHEEL CRANK
G, U	FEED HANDWHEEL CRANK	ROTATE C-C
U	FEED HANDWHEEL CRANK	APPLY FORCE
RL TE		TO COOLANT NOZZLE
G, U	COOLANT NOZZLE	ADJUST POSITION TO DIRECT FLOW OF COOLANT ON TOOL
RL TE		TO LATERAL FEED HANDWHEEL
G, C	LATERAL FEED HANDWHEEL	ROTATE CLOCKWISE

RIGHT HAND

SYMBOL	OBJECT	DESCRIPTION
RL TE		TO LATERAL FEED HANDWHEEL
G*	LATERAL FEED HANDWHEEL	
G*	HANDWHEEL CRANK	
G	HANDWHEEL CRANK	
U	HANDWHEEL CRANK	ROTATE CLOCKWISE
RL TE		TO CARRIAGE BINDER
G	CARRIAGE BINDER	
U	CARRIAGE BINDER	PUSH IN
RL TE		TO LATERAL FEED HANDWHEEL CRANK
G	HANDWHEEL CRANK	
U	HANDWHEEL CRANK	ROTATE CLOCKWISE
U	HANDWHEEL CRANK	ROTATE HANDWHEEL C.

MACHINE

DESCRIPTION
ADVANCE CUTOFF TOOL TO WORK
TRAVERSE CARRIAGE TO LEFT AGAINST STOP
BIND CARRIAGE
HOLD CARRIAGE AGAINST STOP
FEED CUTOFF TOOL
FEED CUTOFF TOOL

\# DOUBTFUL

* "CONTACT" GRASP

TOTAL ACTIVITY CHART

SHEET 10 OF 13

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE	TIME
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND				
	SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION	
	P	CHAMFERING TOOL	MOVEMENT & POSITION RELATIVE TO WORK: MOVEMENT & POSITION OF COOLANT STREAM							GC	HANDWHEEL CRANK	SLIP CONTACT FORCE	V	INITIAL CUT COMPLETE	ADVANCE CHAMFER TOOL				U	HANDWHEEL CRANK	ROTATE C-C RAPIDLY	RETRACT TURRET & ADVANCE REAR TOOL POST	
							I	NONE	NONE							RL TE		TO COOLANT NOZZLE					
1360																							1360
							GC	COOLANT NOZZLE	SLIP CONTACT FORCE							G U	COOLANT NOZZLE	ADJUST POSITION TO DIRECT FLOW OF COOLANT ON CHAMFER					
1370																							1370
1380																							1380
1390																							1390
1400																							1400
										GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION & FORCE							U	HANDWHEEL CRANK	ROTATE C-C SLOWLY	ADVANCE CHAMFER TOOL TO WORK	
1410	M									GC C	CUTTING ACTION	VIBRATION & FORCE	T	CHAMFERING BEGUN	FEED TOOL				U	HANDWHEEL CRANK	ROTATE C-C	FEED TOOL INTO WORK	1410
	R P	"4" CLIP	MOVEMENT & POSITION RELATIVE TO FIXED INDEX							I	NONE	NONE							RL TE		TO LATERAL FEED HANDWHEEL		
							I	NONE	NONE							RL TE		TO LATERAL FEED HANDWHEEL					
1420										GC	FEED HANDWHEEL	SLIP CONTACT FORCE							G	FEED HANDWHEEL			1420
										GC C	CUTTING ACTION	VIBRATION & FORCE							U	FEED HAND-WHEEL	ROTATE C-C	FEED CHAMFERING TOOL INTO WORK & SET DIAL TO "4"	
							GC C	CUTTING ACTION	VIBRATION & FORCE							G U	LATERAL FEED HANDWHEEL	ROTATE C-C				FEED CHAMFERING TOOL INTO WORK & SET DIAL TO "4"	
1430																							1430
1440																							1440
1450																							1450
										I	NONE	NONE							RL TE		TO LATERAL FEED HANDWHEEL CRANK		
	M												V	CHAMFERING TOOL	ADVANCE CUTOFF TOOL								
										GC	HANDWHEEL CRANK	SLIP CONTACT FORCE							G U	HANDWHEEL CRANK	ROTATE RAPIDLY C	ADVANCE TURRET	
							I	NONE	NONE							RL TE		TO COOLANT NOZZLE					
1460	P	CUTOFF TOOL	MOVEMENT & POSITION RELATIVE TO WORK & MOVEMENT OF HAND TO COOLANT NOZZLE, MOVEMENT & POSITION OF COOLANT NOZZLE																				1460
1470																							1470
1480							GC	COOLANT NOZZLE	SLIP CONTACT FORCE							G U	COOLANT NOZZLE	ADJUST POSITION TO DIRECT FLOW OF COOLANT ON CHAMFER					1480
1490																							1490
1500																							1500

TOTAL ACTIVITY CHART

TIME: 1510, 1520, 1530, 1540, 1550, 1560, 1570, 1580, 1590, 1600, 1610, 1620, 1630, 1640, 1650

VISUAL

SYMBOL	OBJECT	STIMULUS
M		
L	LATERAL FEED ENGAGING LEVER	LOCATION
P	LATERAL FEED ENGAGING LEVER	MOVEMENT AND POSITION
M		
P	LATERAL FEED MICROMETER DIAL	POSITION AND MOVEMENT RELATIVE TO FIXED INDEX
M		
L	COOLANT NOZZLE	LOCATION
P MR	CUTTING ACTION	POSITION COOLANT STREAM AND SIZE, SHAPE AND RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO THE RESULTING SHAPE AND FINISH OF WORKPIECE AND COOLANT FLOW
M		
P	MICROMETER DIAL	MOVEMENT AND POSITION RELATIVE TO FIXED INDEX
M		
P. MR	CUTTING ACTION	POSITION COOLANT STREAM AND SIZE, SHAPE & RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL ALSO THE RESULTING SHAPE & FINISH OF WORKPIECE AND COOLANT FLOW
M		
R P	COARSE-FINE FEED SELECTOR	"FINE" AND POSITION
M		
E. MR	CUTTING ACTION	SEE BOTTOM. R.H. TACTILE COLUMN

AUDITORY

SYMBOL	SOURCE	STIMULUS
T	LOCKING PLUNGER ENTERING CATCH	LOW CLICK

TACTILE

LEFT HAND

SYMBOL	OBJECT	STIMULUS
I	NONE	NONE
GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE
GC	LATERAL FEED HANDWHEEL	CONTACT FORCE
I	NONE	NONE
GC		CONTACT SLIP FORCE
I	NONE	NONE
MR	CUTTING ACTION	VIBRATION

RIGHT HAND

SYMBOL	OBJECT	STIMULUS
GC T	INITIAL CONTACT OF TOOL WITH WORK	VIBRATION AND FORCE
I	NONE	NONE
GC P	PLUNGER ACTION & POSITIVE STOP	VIBRATION AND FORCE
I	NONE	NONE

1644 VISUAL, STIMULUS: POSITION COOLANT STREAM & SIZE, RATE, & SHAPE & RATE OF MOVEMENT OF CHIP RELATIVE TO TOOL. ALSO THE RESULTING SHAPE & SURFACE FINISH OF WORKPIECE AND COOLANT FLOW

MEANING

SYMBOL	CONDITION	ACTION
V	TOOL APPROACHING WORK	G SLOW DOWN
T	TOOL IN CONTACT WITH WORK	ENGAGE POWER FEED
A T	POWER FEED ENGAGED	MONITOR CUTTING ACTION

MANIPULATIVE

LEFT HAND

SYMBOL	OBJECT	DESCRIPTION
RL TE		TO LATERAL FEED HANDWHEEL
G, U	LATERAL FEED HANDWHEEL	
RL TE		TO COOLANT NOZZLE
G, U	COOLANT NOZZLE	ADJUST POSITION TO DIRECT FLOW OF COOLANT ON CHAMFER
RL TE		TO LATERAL FEED HANDWHEEL
G*	LATERAL FEED HANDWHEEL	APPLY TOUCH

RIGHT HAND

SYMBOL	OBJECT	DESCRIPTION
U	HANDWHEEL CRANK	ROTATE SLOWLY CLOCKWISE
RL TE		TO LATERAL FEED ENGAGING LEVER
G, U	FEED ENGAGING LEVER	PULL UP POWER
RL TE		TO RELAXED POSITION
UD		FOR TOOL TO CUTOFF PIECE

MACHINE

DESCRIPTION
ADVANCE CUTOFF TOOL TO WORK
ENGAGE FEED

* CONTACT GRASP

TOTAL ACTIVITY CHART

SHEET 12 OF 13

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE	TIME
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND				
	SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION	
1660																							1660
1670							I	NONE	NONE							RL TE		TO COOLANT NOZZLE					1670
1680							GC	COOLANT NOZZLE	CONTACT, SLIP, FORCE							G, P	COOLANT NOZZLE	ADJUST POSITION TO DIRECT FLOW OF COOLANT ON CHAMFER					1680
1690																							1690
1700																							1700
1710																							1710
1720																							1720
1730																							1730
1740																							1740
1750																							1750
1760																							1760
1770																							1770
1780																							1780
1790																							1790
1800																							1800

TOTAL ACTIVITY CHART

SHEET 13 OF 13

TIME	VISUAL			AUDITORY			TACTILE						MEANING			MANIPULATIVE						MACHINE	TIME
							LEFT HAND			RIGHT HAND						LEFT HAND			RIGHT HAND				
	SYMBOL	OBJECT	STIMULUS	SYMBOL	SOURCE	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	OBJECT	STIMULUS	SYMBOL	CONDITION	ACTION	SYMBOL	OBJECT	DESCRIPTION	SYMBOL	OBJECT	DESCRIPTION	DESCRIPTION	
1810																							1810
1820																							1820
	M												V	CUTOFF COMPLETED	DISENGAGE POWER FEED								
1830																							1830
	L	LATERAL FEED ENGAGING LEVER	LOCATION																				
1840							I	NONE	NONE							RL TE		TO LATERAL FEED HANDWHEEL					1840
																			TE		TO LATERAL FEED ENGAGING LEVER		
	MV	LATERAL FEED ENGAGING LEVER	MOVEMENT AND POSITION							P	LEVER ACTION AND POSITIVE STOP	MOVEMENT AND FORCE							G, U	LATERAL FEED ENGAGING LEVER	PUSH DOWN	DISENGAGE POWER FEED	
1850				T	CONTACT OF LEVER WITH POSITIVE STOP	THUD							A T	POWER FEED DISENGAGED	RETRACT TURRET, FEED STOCK & REPEAT CYCLE								1850
1860																							1860
1870																							1870
1880																							1880
1890																							1890
1900																							1900
1910																							1910
1920																							1920
1930																							1930
1940																							1940
1950																							1950

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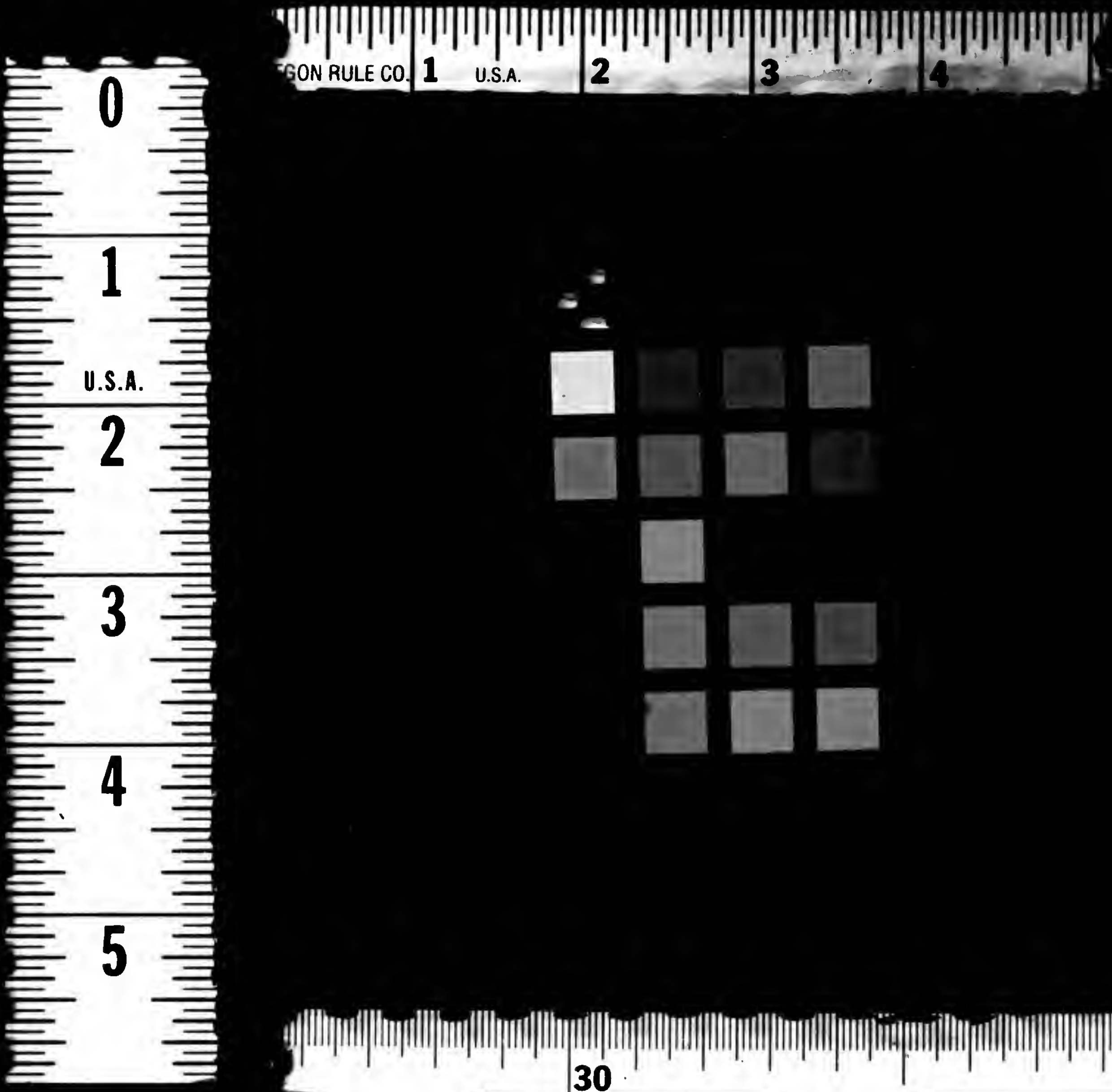
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